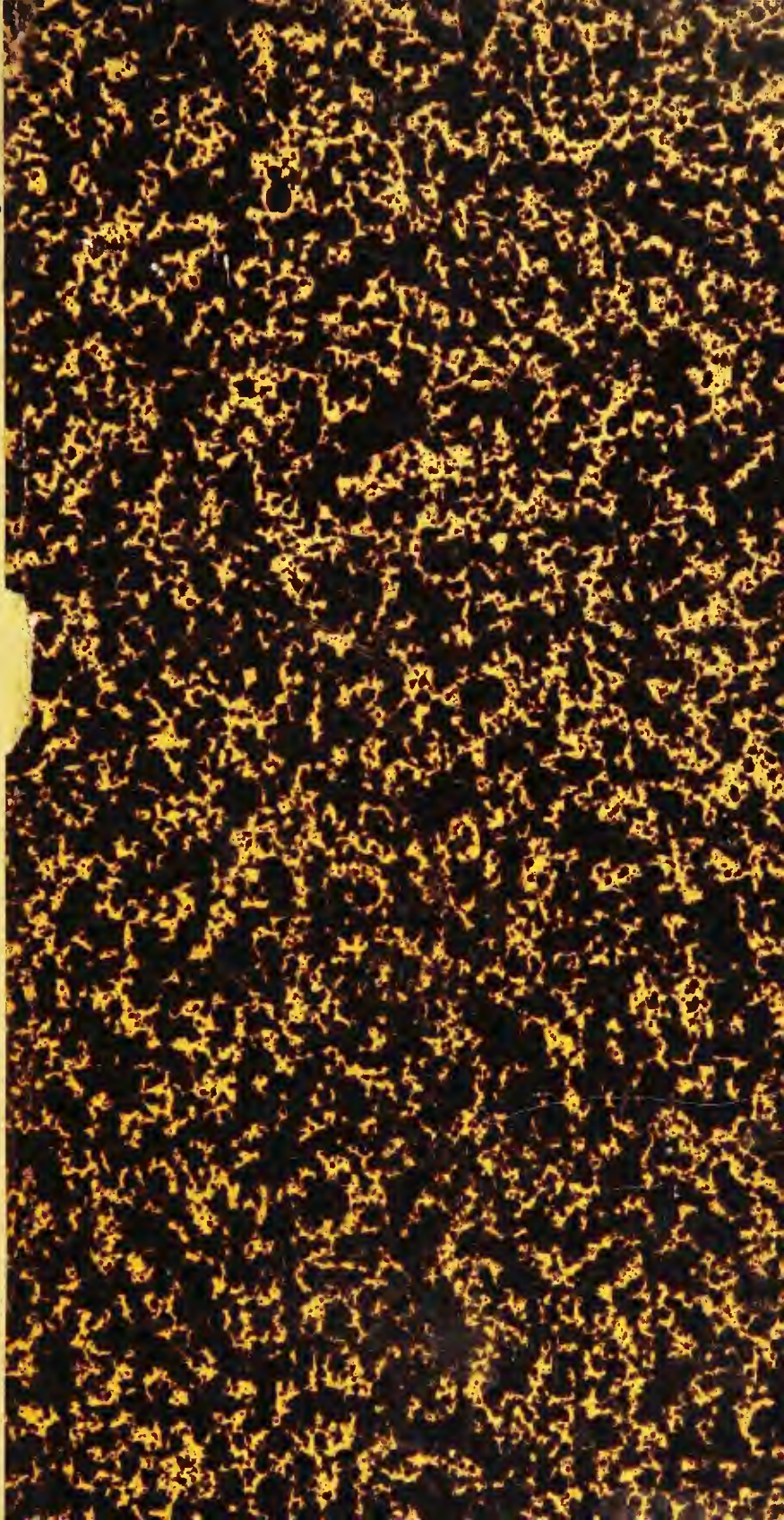

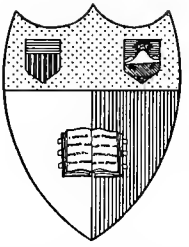

MEMOIRS OF THE GEOLOGICAL SURVEY, SCOTLAND.

THE GEOLOGY

OF

KNAPDALE, JURA AND NORTH KINTYRE

(EXPLANATION OF SHEET 28, WITH PARTS OF 27 AND 29).

BY

B. N. PEACH, LL.D., F.R.S.; THE LATE J. S. G. WILSON; J. B. HILL, R.N.; E. B. BAILEY, B.A.; AND G. W. GRABHAM, M.A.

WITH NOTES BY

C. T. CLOUGH, M.A.; S. B. WILKINSON; W. B. WRIGHT, B.A.; AND H. B. MAUFE, B.A.; AND PETROLOGICAL DESCRIPTIONS BY J. S. FLETT, M.A., D.Sc.

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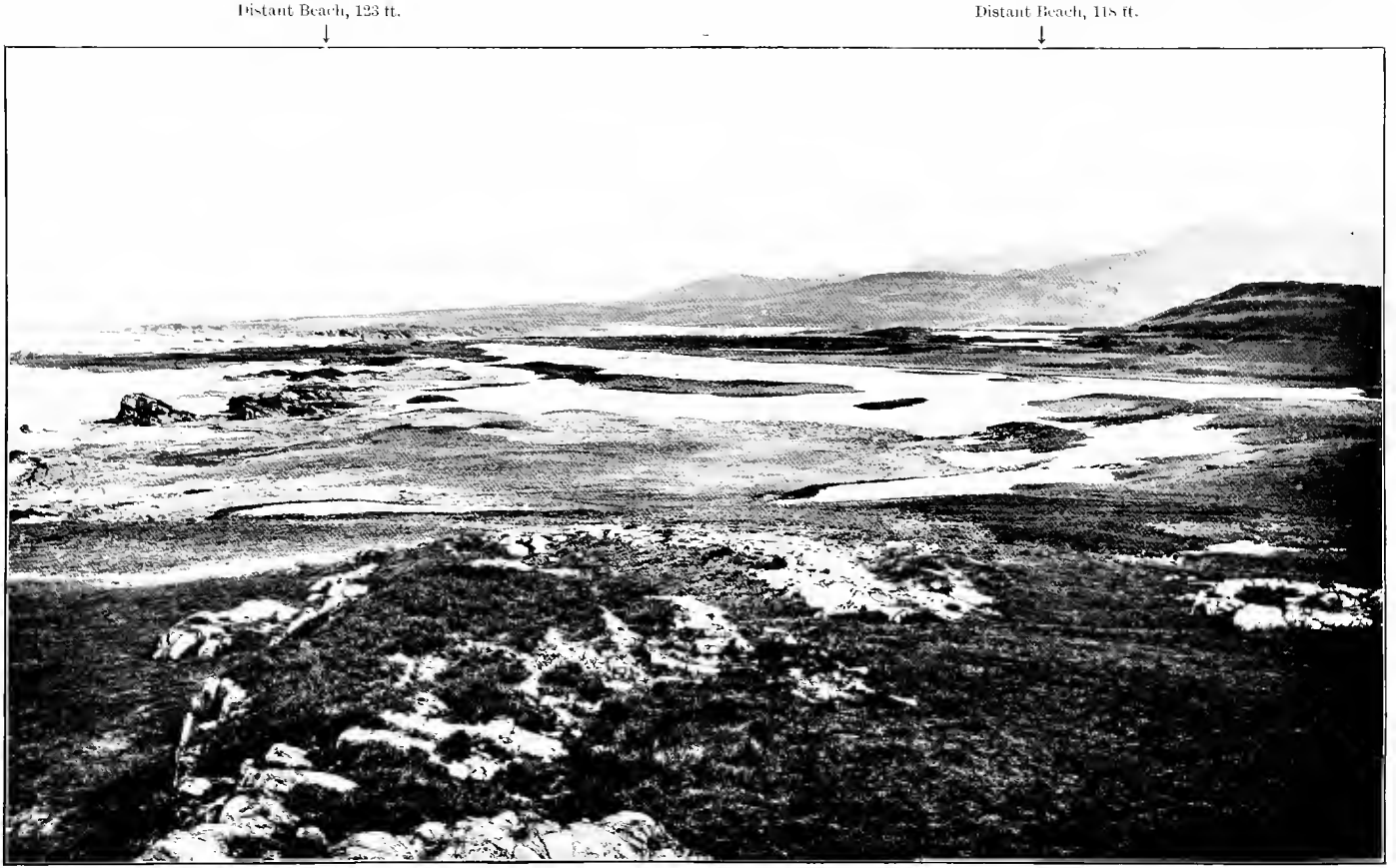

RAISED BEACHES. Shian Bay, West Coast of Jura.

28

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PREFACE.

This Memoir describes the geology of the district included in Sheet 28 of the one-inch map of Scotland comprising the larger portions of the island of Jura and of the district of Knapdale in Argyllshire. The limits of the Sheet are somewhat inconvenient for the purpose of geological description. Although the greater portion of Jura is included within it, the northern part of the island extends into Sheet 36, and a narrow strip of country on the south-eastern side lies in Sheet 27. As the island forms a well-defined natural unit, it is here dealt with as a whole without regard to the limits of the Sheet. For a similar reason small portions of Knapdale, mid-Argyll (east of Lochgilphead) and north-east Kintyre, all of which lie in Sheet 27, have also been described in this Memoir.

The eastern part of the mainland tract was surveyed by Mr. J. B. Hill from 1885 to 1888. After Mr. Hill's transference to Cornwall, Dr. B. N. Peach was in charge of the district for most of the period, and himself mapped the Tayvallich peninsula and the north end of Jura. Mr. S. B. Wilkinson, who was transferred to the English Survey in 1898, had surveyed the island of Jura with the exception of the north-west corner. Mr. E. B. Bailey subsequently re-examined parts of the island and, with the help of notes furnished by Mr. Wilkinson, has prepared the chapters on its geology. The late J. S. Grant Wilson surveyed a considerable tract on the east side of Loch Sween, and also the area between Ormsary House and Kilberry. Mr. C. T. Clough, the late Mr. R. G. Symes, Mr. W. B. Wright, Mr. H. B. Maufe and Mr. G. W. Grabham have helped to map the district, and (with the exception of Mr. Symes) have supplied the descriptions of the areas they surveyed.

The petrology of the igneous rocks has been investigated principally by Dr. Flett, but notes furnished by me and by Dr. Hatch to the field geologists at various times have also been made use of. Chemical analyses have been supplied by Mr. Radley.

The photographs reproduced in Plates I. to IV., VI. and VII. were taken by Mr. Lunn, and the photomicrographs in Plate V. by Mr. T. C. Hall.

J. J. H. Teall, Director.

Geological Survey Office,
28 Jermyn Street, London,
13*th October*, 1910.

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GEOLOGY OF KNAPDALE, JURA AND NORTH KINTYRE.

CHAPTER I.

PHYSICAL FEATURES.

THIS memoir describes the area comprised within Sheet 28 of the one-inch map of Scotland, and the natural extensions of that region as far as Loch Fyne (Sheet 29) to the east, the Sound of Islay (Sheet 27) to the west, and the Gulf of Corryvreckan (Sheet 36) to the north. The district lies within the county of Argyllshire, and in comparatively recent geological times formed part of the archipelago fringing the south-west Highlands. It includes the island of Jura and the northern part of the peninsula extending from the Crinan Canal to the Mull of Kintyre, a peninsula which, about the end of the glacial epoch, was itself a chain of islands severed by channels occupying the Crinan hollow and the cleft connecting East and West Loch Tarbert. In that period Jura was likewise divided by an extension of the estuary of Loch Tarbert* which indents its western shores.

The superficial area amounts to about 515 square miles, and, so far as Sheet 28 is concerned, is approximately equally apportioned between the land and sea. The water area is principally confined to the Sound of Jura and the small fiords of Loch Sween, Loch Caolisport and West Loch Tarbert, which may be regarded as its tributaries. The sea area also includes a small portion of the outer Atlantic washing the western shores of Jura on either side of Loch Tarbert.

The mainland tract consists of the northern portion of Kintyre and of the greater part of Knapdale (which was formerly included in the district of Kintyre), and lies in the parishes of North Knapdale, South Knapdale, and Kilcalmonell and Kilberry. The small tract east of Loch Gilp lies in the parish of Kilmichael Glassary, while the whole of Jura is included within a single parish. J. B. H.

Viewed broadly there is a peculiarity in the scenery of this district, which it shares with the greater part of the coastal tract of Argyllshire. Although there is an endless repetition of ridge and hollow, island and loch, monotony rather than variety is the general

* It is interesting to note the use of the name Tarbert twice in this district, with its usual signification, denoting the presence of a low isthmus connecting two navigable waters.

effect produced. The ridges attain a roughly uniform summit-level, seldom exceeding a thousand feet, and the whole appears to be a much dissected plateau. From the latter the Paps of Jura rise with singular beauty, in an isolation which is all the more remarkable inasmuch as it has no counterpart in the geological formation of the island. The origin of the plateau feature is not clear. It may be regarded either as a plain of marine denudation or as a peneplain of subaerial erosion. It is uncertain whether the major hollows of the district, such as the Sound of Jura, originated before or after the formation of the plain. It is likewise uncertain whether its level has been affected by warping subsequent to its production. From its relation to the Tertiary dykes it seems probable that the plateau was cut after the last great outbursts of the volcanoes of the Western Isles. B. N. P.

The topography, apart from this plateau feature, bears a most intimate relation to the geological structures. The district is built up in the main of an assemblage of sedimentary schists belonging to the Dalradian sequence, associated with numerous intercalated parallel bands of igneous rock (epidiorite). The entire group strikes across the region in a north-easterly and south-westerly direction, and this trend has guided the course of the denudation which has developed a topography characterised by a succession of parallel ridges and troughs. Of the latter especially good illustrations are afforded by the Sound of Jura and the basins of Loch Sween, Loch Caolisport and West Loch Tarbert, all representing the submergence of an ancient valley system. The basin formed by Loch Gilp and lower Loch Fyne bears, however, no clear relation to the strike of the schists, and the inception of this trough has perhaps been determined by a shatter-belt along a line of fault which lines its bed. There are also some transverse valleys more or less independent of geological structure, of which the Tarbert valley of Jura is perhaps the most noteworthy example.

The most rugged scenery is presented by the quartzite tract of Jura, culminating in the Paps, and by the region of Kintyre. The latter belt is built up of the Beinn Bheula Schists, that not only reach a higher degree of metamorphism than the other rock bands of the sequence, but also exhibit a more extreme type of contortion. The most elevated portion of the mainland, on the other hand, is formed by the quartzite belt that traverses the region between Stronchullin and Loch Stornoway; the highest part, marked by the ridge of Sliabh Gaoil, attaining an altitude of 1840 ft. The epidiorite sills are most profusely distributed in the northern tract, where the more rapid denudation of the enclosing sediments has given rise to a close succession of ridges and hollows that forms the prevailing type of scenery in that area. Limestone and slate enter largely into the composition of the district south of Tayvallich, and have contributed to the enrichment of the verdant pastures that so vividly contrast with the otherwise rocky nature of this region.

The bands of schist are also pierced by dolerite and basalt dykes which belong to two epochs of time; the earlier are probably of late Carboniferous age and follow an east and west course, while the later and more dominant set have a prevailing north-westerly direction and are referred to the early Tertiary period. These dykes have

principally set their mark on the topography by their erosion, which has in many cases given rise to gorges and chasms. Along the west coast of Jura, however, they project as great walls and buttresses, stacks and arches, and form the main attraction of what is one of the most impressive coast-lines in Scotland.

Faults, transverse to the prevailing surface features, have also modified the scenery: one of the most notable examples of this modification is afforded by the fault which lines the cleft crossing North Knapdale from Loch Sween to Loch Fyne, along the valleys of the Lussa and Inverneil.

As will be seen in the sequel, this region was overridden in the glacial period by an ice-sheet creeping in a westerly and south-westerly direction towards the Atlantic, and although the glacial deposits that have survived are comparatively meagre, sufficient have remained to modify the scenery. Occasional large spreads of boulder clay, especially in the district of Kilberry and along the southern shores of West Loch Tarbert, form features which diversify the landscape, while erratic blocks, often quaintly poised, are scattered over the whole region.

While the fiords represent ancient valleys that have been submerged beneath the waves, the raised beaches point unmistakably to an upheaval of the sea floor. On the mainland the most extensive of these deposits occupy protected hollows along the coastal margin, but this is not the case in Jura, where large spreads of naked shingle are scattered at every level on the western slopes up to a height slightly exceeding the 100-foot contour. Throughout the whole district one beach in particular, at an elevation of about 25 ft., is conspicuous for the amount of erosion that marked its formation. The western coast of Jura with its cliffs and caves, the latter inhabited during summer by lobster fishers, presents the finest examples of this erosion, but the headland south of Kilberry also furnishes a noteworthy illustration.

Although the area occupied by the raised beach deposits is comparatively small, and the rock notch referred to is always narrow, still both play a very important economic rôle. Such platforms fringing a mountainous district present natural sites for the roads, towns and villages, and have also been taken advantage of for the mansions and demesnes of the various estates, and occasionally for the farmsteads. The towns of Lochgilphead and Ardrishaig have been built on these deposits, and the narrow platform to the south of Ardrishaig is occupied by villas that stand in flourishing gardens. Tarbert, on the other hand, in which these deposits are absent, is built practically on the solid rock, the houses being situated mainly on the rocky slopes, in which gardens are absent or meagre. The safe anchorage, however, has been of paramount importance for the fishing industry, while its contiguity to West Loch Tarbert has also contributed to the advantages of its situation, which have outweighed other considerations.

The streams and rivers of the district although numerous are of small size, those of Jura being the most important. Lakes are likewise abundant but never of large size, as a glance at the map will show. The sites of ancient tarns are occasionally occupied by peat, while in other cases the lochs that still remain are in process

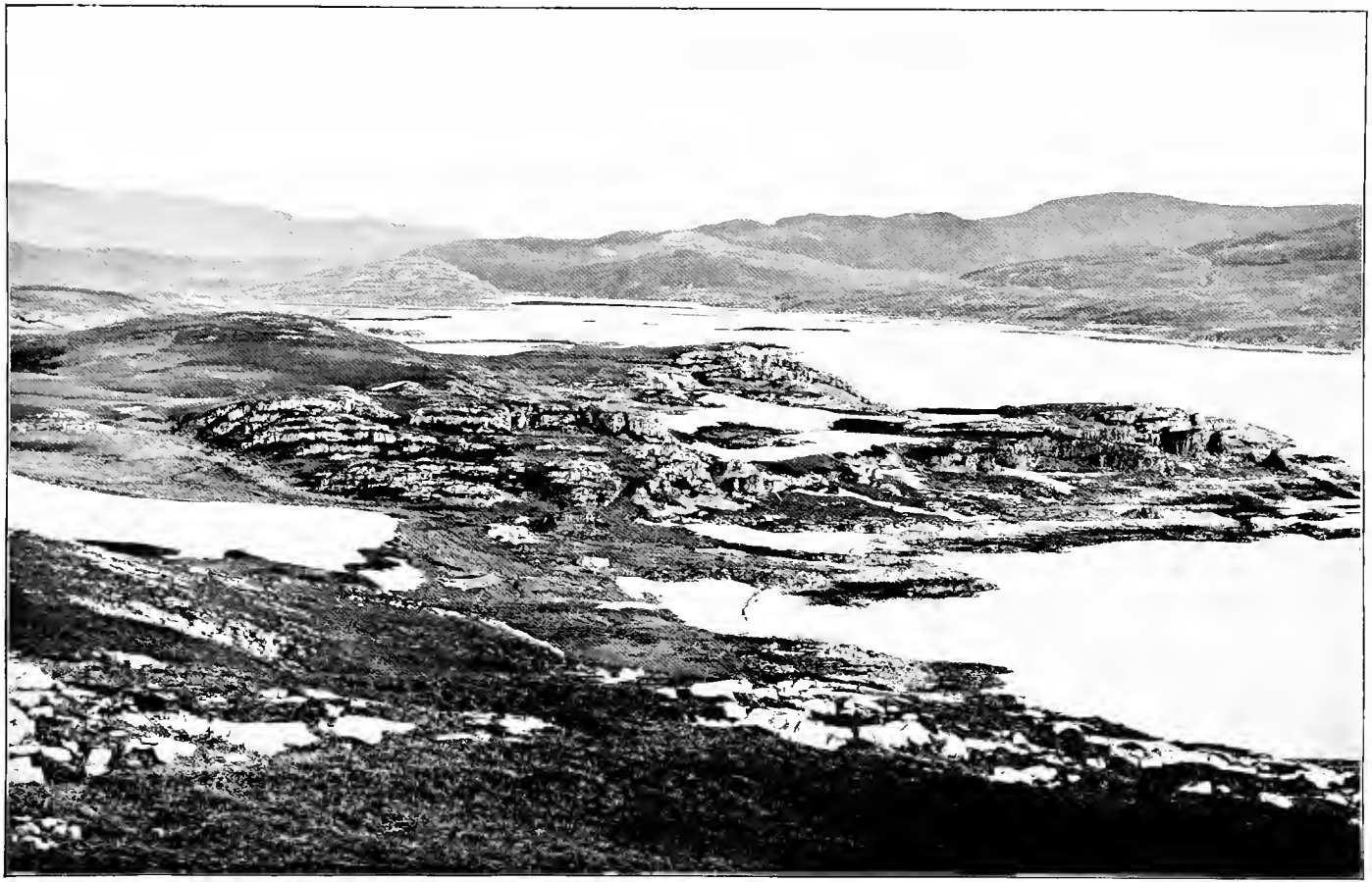
of extinction. In the northern region the larger sheets of water represented by the Cam Loch, Loch Clachaig, the Gleann Loch, Loch na Faoilinn and Loch an Add, have been considerably augmented by artificial embankments to provide reservoirs for feeding the Crinan Canal.

The principal centres of population are situated on the shores of Loch Fyne, at Lochgilphead, Ardrisbaig and Tarbert, the inhabitants of which in 1901 numbered 1313, 1285 and 1214 respectively. Lochgilphead serves as a market town for the northern district, while Tarbert supplies a similar function in the southern area. The latter is also one of the principal headquarters of the Loch Fyne herring industry, while smaller fishing fleets pertain to Ardrishaig and Lochgilphead. The Crinan Canal, which connects Loch Fyne with the Sound of Jura, is entered at Ardrishaig, and, should that canal be enlarged, as at present contemplated, so as to afford a passage for larger ships, the value of Loch Fyne as a waterway connecting the Clyde with the West Highlands will be materially enhanced, while Ardrishaig and Lochgilphead will then rise in importance.

Apart from these towns the region is but sparsely populated; the fishing villages of Tayvallich and Kilberry, both on the mainland, may, however, be mentioned, while Milltown, better known as Small Isles, serves as capital for the comparatively uninhabited island of Jura.

Ardrishaig, Tarbert, both East and West, and Small Isles are the only ports with a regular steamboat service. The whole of the mainland tract is rendered accessible chiefly by mail gigs and coaches running in connection with the steamers. The southern end of Jura relies not only upon its own port at Small Isles, but also upon Port Askaig across the Sound of Islay, while the northern end depends largely upon direct communication with the mainland. Lowlandman's Bay, north of Small Isles, although not used as a regular port, is a well-known and valued anchorage for vessels waiting upon favourable conditions before rounding the Mull of Kintyre.

Almost the whole of Jura is deer forest, but the hill pastures of the mainland are under sheep, while the proportion of cultivated land is everywhere insignificant. J. B. H.



RAISED BEACHES. Bagh Gleann Righ Mor, Loch Tarbert, Jura.

CHAPTER II.

INTRODUCTION TO THE GEOLOGY.

Points of General Interest.

The district supplies two or three examples of specially attractive geology. The naked shingle beaches of the western coast of Jura, reaching to elevations of a hundred feet or so above the wash of the modern sea, are impressive in the extreme (Plates I., II., VI. and VII.). So, too, are the caves, cliffs, arches and stacks of the lowest of the raised beaches along the same beautiful shore-line.

The mainland also provides material of interest for the general geologist, especially in the splendid coast sections south of Tayvallich, where there are varied exposures of pillow lavas intercalated among the sedimentary schists of the country (Plate III.).

To those who are interested in the complicated study of the Highland Schists the district, as a whole, is of prime importance. Several well-known divisions of the Dalradian * succession here reach the sea, and their nature and marginal relations, involving questions of the original sequence and present structure, can be especially well studied. A low degree of metamorphism characterises much of the area, and is a continuation of the conditions described some years ago by Mr. Hill in the Loch Awe district. This greatly facilitates many researches which could scarcely be prosecuted among highly schistose rocks: the discovery of the true nature of the pillow lava group by Dr. Peach was thereby rendered possible, and in turn promises to illuminate many obscure points in the geology of the South-West Highlands generally.

History of Research.

The region attracted a considerable amount of attention in the early days of Scottish Geology. It is interesting to find Pennant, in 1790, recognising the volcanic nature of the basalt dykes of Jura, but taking it for granted that the dyke fissures were filled by lava flowing in from above (p. 248).† Jameson later, in 1800, illustrated the fantastic erosion forms which these dykes assume along the west coast of the island (Plates facing pp. 167 and 169).

Pennant had referred to the occurrence of white quartzy rocks made of small grains and also of cinereous slate. Jameson amplifies these decriptions, and states that the granular quartz rises from

* The term Dalradian, derived from the Scoto-Irish kingdom of Dalriada, was introduced by Sir A. Geikie to include the crystalline schists of the north of Ireland and the centre and south-west of the Scottish Highlands.

† The pages and plates referred to in this section apply to works the titles of which are given in the bibliography.

beneath the micaceous schistus at an angle of about 45° (p. 174). He also mentions the occurrence of *ardesia tegularis* (roofing slate) near the junction of the granular quartz and the schistus, and refers to the fact that it had been quarried at one point. His theoretical discussion of the origin of the granular quartz is very interesting. Since the granular quartz contains quartz, felspar and mica, it must, according to Jameson, be a "true granite," one of the very earliest chemical precipitates from the primitive ocean. It remained for Macculloch, in 1814, to point out that the quartz and felspar grains are of the nature of rounded pebbles, and that near the eastern side of the island the quartz rock passes into breccia with included slate fragments. Thus he does "not hesitate to conclude that the quartz rock of Jura is a mechanical deposit, or a rock recomposed from fragments of older ones" (p. 455). He therefore claims that the quartz rock is not primitive in the Wernerian sense; he also strongly doubts whether this term can be applied to the micaceous schistus dipping off the quartz rock.

While Macculloch cleared up the nature of the Jura quartzite in 1814, he failed, even in his classical account of the Western Isles (1819), to distinguish the igneous nature of the epidiorite sills of the east part of Jura, in spite of their conspicuously porphyritic character (p. 212). He also decided against the igneous interpretation of the similar rocks so extensively developed on the mainland (p. 292); in fact, this point of prime importance had to wait until the publication of Jamieson's paper, in 1860, on the structure of the South-West Highlands (p. 140).

Returning to Macculloch, we find a clear description of the lie of the strata from Tarbert on the mainland to Jura (p. 287), showing the way in which the beds dip in towards a central axis along Loch Sween, where they assume a vertical position. He even noted the more local verticality of the strata in the neighbourhood of Barmore, on Loch Fyne.

The special abundance of basaltic dykes in south Jura and north Islay also attracted his attention (p. 213). This feature he connected with the occurrence of amygdaloidal traps in Glas Eilean, in the Sound of Islay. The discovery of this interesting outcrop of lavas is characteristic of the thoroughness of the man, and the possible connection which he suggested between lavas and dykes cannot yet be regarded as unworthy of consideration. The basaltic dykes are, however, now known to be post-Carboniferous and probably Tertiary, while the lavas of Glas Eilean have been referred by Sir Archibald Geikie to the Old Red Sandstone period.

In 1824 attention was given to the raised beaches of Jura. Vetch describes the caves and the great spreads of naked shingle as evidences of upheaval. He was, however, unaware of the wide extent of similar though less conspicuous phenomena along the Highland seaboard, and, curiously enough, he also regarded the upheaval of Jura itself as limited to about 40 ft. Bedford, in 1855, showed that the raised beaches extended to 105 ft. above sea-level. He made sketches of the beaches, but unfortunately these do not seem to have been published.

Jamieson, in the paper referred to, printed in 1860, not only demonstrated the igneous nature of the epidiorites of Knapdale, but gave an excellent description of the various sedimentary schists

of the mainland tract. Having realised the true character of the epidiorites, he was able to dispense with Macculloch's "Chloritic Formation." He naturally took a simpler view of structure than is in vogue at present: he correlated the Dunoon Phyllites with the Ardrishaig Phyllites, to the north-west, across the Cowal "anticline"; and these latter with the Port Ellen Phyllites of Jura, further to the north-west again, across the Knapdale "syncline." These correlations were certainly premature.

Two years later, in 1862, the same author published his observations on the glaciation of the district with a general striæ map (Fig. 5, p. 183). He insisted that the ice-stream swept across Knapdale from Loch Fyne, following a course which was necessarily in large measure uphill (p. 177). He correctly compared the conditions of the period when this occurred with those prevailing in Greenland to-day.

In 1863 A. Geikie described an arctic shell bed at the head of Loch Gilp in connection with an account of the glacial phenomena of Scotland in general. His description was amplified by Crosskey in 1867, and in 1871 Crosskey and Robertson published a very important list of the shells obtained from the deposit. In 1886 Crosskey gave an account of the glaciation of Knapdale, and published another important list of arctic shells, in this case obtained from the shores of Loch Sween.

In 1888 Anderson extended Jamieson's glacial researches by visiting Jura, which he found had been traversed by ice moving west out of the Sound. He notes abundant boulders carried from the mainland, and also clear evidence of the action of the ice-sheet at 1200 ft. above sea-level. He further describes valley moraines, which he attributes to a distinct and much later glaciation.

Mr. Hill began the regular geological survey of the district along the shores of Loch Fyne in 1885, and the work has gone on intermittently since that date. In 1892 Sir Archibald Geikie, in his Geological Map of Scotland, included the results so far obtained, and since 1898 brief accounts of current work have been published in the *Summaries of Progress of the Geological Survey*. The final results of the survey are given in the present memoir and need not be recapitulated here.

E. B. B.

Tabular Statement of Formations with Brief Descriptions.

The following list shows the different formations and rock groups described in subsequent chapters. The order of arrangement of those schists that have been derived from sedimentary or contemporaneous igneous rocks is not intended to indicate their relative ages, these not having yet been determined with certainty. No rocks of sedimentary origin have been found to help to fill up the great gap between the Pleistocene and the schistose sediments, but this gap is no doubt represented in part by intrusive igneous rocks of several ages.

Recent and Pleistocene—

Peat.
Freshwater alluvia.
Marine alluvia including raised beaches.
Morainic drift.
Boulder clay.

TERTIARY ?—
North-West dolerite and basalt dykes.

LATE CARBONIFEROUS ?—
East and West quartz dolerite dykes.

LOWER OLD RED SANDSTONE ?—
Porphyrite, felsite and lamprophyre intrusions.

METAMORPHIC ROCKS OF THE MAINLAND—
Intrusive sills of epidiorite, hornblende schist and chlorite schist.
Beinn Bheula Group.
Green Beds.
Glen Sluan Schists.
Loch Tay Limestone.
Stonefield Schists with limestone outcrops.
Erins Quartzite Group; this group, with predominating quartzite, includes some limestones and wide bands of phyllites, which, at Stronchullin, are partly black.
Ardrishaig Phyllite Series with subordinate quartzite and limestone; thin calcareous conglomerate bands are mapped in places.
Loch Awe Group; pebbly quartzites, black and grey slates, and limestones; conglomerate with granitoid boulders mapped in one locality; schistose volcanic rocks.

METAMORPHIC ROCKS OF JURA—
Sills and dykes of epidiorite.
Port Ellen Phyllites.
Jura Quartzite with black and grey slates and phyllites.

Though the relative ages of the schists is still a matter for discussion, their chief groups are met with in a definite geographical order as we advance across the general N.N.E. strike from the south-eastern corner of the area to the Sound of Jura. This order has been presented as far as possible in the foregoing list, the Beinn Bheula Group, which occurs the furthest south-east, being placed near the beginning, the Green Beds next, and so on. Jura, being completely isolated by the sea, has been considered by itself.

The Beinn Bheula Group includes a large proportion of highly altered schistose grits, together with albite schists and other pelitic schists. The breadth across the strike is nearly six miles. It is to be noted that in the south-east part of the area the general dip is south-east, while in the north-western half it is north-west.

The Green Beds proper are greenish schists, rich in epidote and chlorite and frequently also in clastic grains of quartz and felspar, but the Green Bed Group is only partially composed of such distinctive beds; it contains also many sheared grits of normal character and pelitic mica schists, as well as transitional types between the Green Beds proper and the normal sheared grits. The outcrop of this group lies south-east of the Loch Tay Limestone, and is rather more than half a mile broad, but other Green Beds also occur north-west of this limestone.

The Glen Sluan Schists are a thin division of quartzose mica schists in which Green Beds occur only rarely. They have been separated from the main Green Bed Group in parts of Cowal and in Sheet 28.

The Loch Tay Limestone is one of the most distinct and important beds in the area, having been traced right across the Highlands.

The Stonefield Schists represent, in part at least, the Garnetiferous Mica Schist of the Southern Highlands. They consist in the main part of quartzose mica schist.

The Erins Quartzite Group and the phyllitic group of the Ardrishaig Series, together with the associated schistose igneous rocks, occupy about half the mainland described. The bands of quartzite in these groups are much finer-grained than most of those in the succeeding Loch Awe Group. The Erins Quartzite Group is divisible into two portions by the occurrence, near the middle, of a subordinate group of phyllites—the Stronchullin Phyllites. Another belt, in which phyllite is prominently represented, has been separated from the southern portion of the Erins Quartzite outcrop, but is not of so much interest as the Stronchullin band. The Stronchullin Phyllites include some leaden, and in places graphitic phyllites, which may perhaps be on the horizon of some portion of the Ardrishaig Phyllites of Upper Loch Fyne;* but, on the other hand, it is also possible that they represent the graphitic schists of St. Catherine's,† which lie immediately south-east of the Ardrishaig Series and are well exposed about eighteen miles north-east of Stronchullin.

However this may be, it is clear that in the south-eastern portion of the Ardrishaig Series the proportion of quartzite increases greatly as the beds are traced in a south-westerly direction from the centre of Upper Loch Fyne. This change doubtless depends on variation of original deposition, as was stated by Mr. Hill some years ago.‡

The quartzites of the Loch Awe Group are usually more massive and pebbly than the Erins Quartzite. The pebbly grit, which has been found at the south-eastern margin of the former group for a few miles north of Kilmory Bay, sometimes contains pebbles of quartz and quartzite an inch and a half long, together with still larger pieces of limestone and black slate. In considering the significance of these pebbly beds, it has, however, to be noted that somewhat similar but thinner pebbly beds have also been found in various horizons further south-east, under such circumstances that they must be regarded as parts of the Ardrishaig Series, not folded-in portions of the Loch Awe Group.

The limestones and slates of the Loch Awe Group are exposed in two distinct areas. The more important outcrop is situated in the peninsula south of Tayvallich, and the examination of this district has led to a new interpretation of the relations of these rocks. Dr. Peach and Mr. Bailey now regard the main mass of limestone and slate as superimposed upon and younger than the quartzites, with which they are linked by a transition zone made

* This is the view preferred by Mr. Hill.

† "The Geology of Cowal," *Mem. Geol. Survey*, 1897, pp. 53 and 54. "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, p. 31.

‡ "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, p. 35.

up of alternations of the three types of sediment. The inference in regard to the later age of the limestone-slate portion of the group has been based entirely upon a study of the slaggy tops of the associated lavas, the contrast between top and bottom in this case giving a clue to the original order of succession. Among the many other points of interest concerning the development of the Loch Awe Group in the Tayvallich peninsula, we need only mention here the occurrence of a conglomerate containing boulders and pebbles of granitoid rocks foreign to the district but identical with those found in the well-known conglomerates of Schichallion, Islay and the Isles of the Sea.

The Jura assemblage of schists in a general way recalls that of the Loch Awe Group of the mainland. The correspondence is too vague, however, to admit of a confident correlation.

Schistose basic intrusive sills are extremely common throughout the whole area, with the exception of the greater part of Jura and the south-eastern portion of the mainland—the part composed of the Beinn Bheula Group. They occasionally form outcrops a third of a mile broad or more, and on the north-west side of Loch Caolisport and Loch Errol they comprise about half the rock both in the Ardrishaig Phyllites and the Loch Awe Group.

The general strike of the schists is N.N.E., as already noted, but this can be said with greater truth about the foliation than about the bedding, for the latter is frequently folded while the former is steady and approximately parallel to the axial planes of the folds which affect the bedding.

The most general direction of the dip of the foliation is W.N.W., but there are important exceptions to this rule. In the south-eastern part of the Beinn Bheula Group the general dip both of foliation and bedding appears to be south-east, corresponding to that on the south-east side of the anticline of foliation of Cowal,* and on the north-west side of this there is a flat belt, where the foliation is often nearly horizontal, continuing the flat belt of Cowal. Near the head of West Loch Tarbert, about four miles further N.N.W., the foliation again changes inclination and becomes nearly vertical for a short space. Between this locality and Loch Sween the general dip of foliation is W.N.W., but at Loch Sween it changes again through the vertical and becomes E.S.E. In the part of Jura included within this description the dip is almost constantly in this E.S.E. direction, except near the Sound of Islay, where it shows a good deal of irregularity.

In Jura there are several dykes and sheets of porphyrite, felsite and lamprophyre, and some of the latter are cleaved. On the mainland a few small lamprophyre sheets are seen on the coast between Stronchullin and Artilligan.

The East and West dykes of quartz dolerite are not numerous but sometimes of considerable thickness—even more than 50 yds.

* "The Geology of Cowal," *Mem. Geol. Survey*, p. 82.

One passes Tayvallich, rather more than a mile south of the north margin of one-inch map 28. Another strikes a little south of the head of Loch Caolisport, and at least two more are found five or six miles further south. Some of these dykes are no doubt continuations of East and West dykes which form prominent features in the Central Valley of Scotland (see Fig. 6), where one of the group is cut by a faulted intrusive sheet considered to be of late Carboniferous, or Permo-Carboniferous, age.*

The dykes supposed to be of Tertiary age have generally north-west and N.N.W. directions, and are somewhat more numerous than the East and West dykes, though usually thinner. Except in a belt of country crossing the southern part of Jura, they are much less abundant than in many other districts of the West of Scotland, and in traverses across their general strike it is rare to find more than three or four in the distance of a mile (see Fig. 7).

The largest spreads of boulder clay lie on the flatter slopes between the head of Loch Caolisport and Kilberry Head, and also in the neighbourhood of Whitehouse, West Loch Tarbert, but they are comparatively small and thin compared to those found in many other parts of Scotland.

Except in the glens of Jura and in Glen Lussa, north of Bacoch's Seat, no morainic drift has been observed anywhere in the area.

Along most of the coast only two raised beaches have been noticed. The lower seems to correspond to the 25-foot beach of the Clyde, but is in this area often at a slightly higher elevation; the upper is the 100-foot beach, and, except on the west of Jura and south of Kilberry, is for the most part represented by the arrested deltas at the mouths of streams. C. T. C.

* *Summary of Progress of the Geological Survey* for the year 1904, p. 118. Sir A. Geikie, *Quart. Journ. Geol. Soc.*, "Presidential Address," 1892, pp. 140–143.

CHAPTER III.

THE METAMORPHIC ROCKS OF THE MAINLAND.

I.—The Beinn Bheula Schists.

LITHOLOGICAL CHARACTERS.

The Beinn Bheula Schists, which take their name from a mountain in the adjoining district of Cowal, where they are extensively developed, occupy a wide area in the north-eastern portion of Kintyre, falling partly within the district to be described in this memoir. The general characteristics of the group have already been presented in the *Geological Survey Memoirs* on Cowal * and Mid-Argyll;† but, as its lithology and structure have marked affinities with other groups that succeed it, the description of its salient features will be treated in some detail.

The dominant rocks of this series are gneissose grits and granulitic biotite gneisses, while the more pelitic types represented by mica schists occupy a comparatively subordinate position. It is only in the coarser-grained rocks that any decided traces of the original clastic structure are preserved, and even in these they are more apparent in the hand specimens than under the microscope. This type is well represented by specimens from near the northern limit of the group, at a point on the shore one mile south of Barmore Island (3333),‡ and from the neighbourhood of Colindrach, which lies just beyond the southern boundary of the map (3685). These are gneissose rocks containing pebble-like fragments of quartz, often of a bluish hue, and white or pink oligoclase. These grains are about one-eighth of an inch in diameter and usually of lenticular form, and are embedded in a granulitic matrix which is traversed by wavy micaceous films. Under the microscope the rocks are seen to be holocrystalline and to possess a micro-flaser structure. The lenticles or phacoids consist of more or less broken grains of oligoclase and quartz, which may occur either as individuals of considerable size or as granulitic aggregates with tail-like endings. The *flaser* consists of microcrystalline material with which both brown and white micas are associated. Chlorite, iron ores and calcite occur as unimportant accessories. The microcrystalline material of the phacoids often blends with that of the flaser, so that the outlines of the pebble-like fragments are usually much less marked under the microscope than in the field exposures. The

* "The Geology of Cowal," 1897, pp. 38–45, 76–91, 171–234, 295–300.

† "The Geology of Mid-Argyll," 1905, pp. 12–17, 59–61, 72–84.

‡ Numbers in parentheses refer to sliced specimens in the Geological Survey collection.

micas occur in plates with well-developed basal planes but without definite boundaries in the prismatic zone. The lath-shaped sections of biotite are strongly dichroic, varying from yellowish brown to a very dark brown. The mineral is not of the reddish brown colour so common in baked sedimentary rocks near granite margins, but agrees rather with that of granitic rocks and igneous gneisses.

The granulitic gneisses resemble the finer-grained portions of the rocks above described, but the micas tend to be arranged in more parallel folia, imparting a laminated structure. They are well illustrated by specimens from the neighbourhood of Colindrach (3683, 3686). In these, the granulitic folia are usually less than 1 mm. in breadth and are formed of a quartz-felspar mosaic, while the micaceous folia are thinner and are essentially composed of the two micas mentioned above. One specimen (3686) is traversed by planes of secondary schistosity, along which the micas have been more or less concentrated.

While the above may be taken as representing the dominant rock types, specimens from this series also include fine-grained, platy, quartzose, garnetiferous gneiss or mica schist (2912), dark greenish schist containing chlorite as well as two micas (3684), a rock composed of white mica and some chlorite (3347), and albite schist, in which small and more or less idiomorphic albites lie as micro-porphyritic constituents in a matrix of brown biotite and a pale green mica (3801).

From the foregoing remarks it will be seen that we are dealing with a group of crystalline schists of an advanced type of metamorphism but varying in its deformation. While in some instances the original clastic condition of the rock has survived, there is a passage by insensible gradations into bands where such structure has been destroyed.

The physical relations, both of the extreme and intermediate types, are quite obvious. Coarse gneissose grits and schistose bands of more pelitic composition succeed one another in broad zones, and everywhere the stratification is well brought out by the close alternations of coarser and finer bands precisely analogous to those in normal aqueous deposits; in fact, their study in the field admits of no other conclusion but that they represent the metamorphosed product of a sedimentary series.

The grit bands range from seams in which the pebbles are half an inch long to others of the finest texture; beds in which the component grains approximate in dimensions to peas are common, while others frequently carry scattered pebbles of this size in a matrix of fine texture.

These rocks are composed essentially of quartz, felspar and mica, the two former minerals often occurring as original constituents, but more usually representing the metamorphic products evolved in the process of reconstruction. The mica, which is represented by biotite and white mica, is probably in all cases secondary. The clastic grains are apparently confined to quartz and felspar; the former is usually opaque white, but sometimes bluish, recalling the quartz frequently found in the epidiorites and the Lewisian Gneiss; while the felspars, which, so far as they have been determined, are

confined to oligoclase, present white or pinkish hues. In the field the pebbles of quartz and felspar usually show partial granulitisation, while some, which do not betray this aspect to the naked eye, reveal under the microscope granulitisation and recrystallisation on their borders. As a general rule quartz pebbles considerably preponderate over those of felspar, which are sometimes pink but more often white.

The deformation of the clastic grains is attended with much variation. In the coarse bands that are composed almost entirely of the larger individuals, the latter have been often stretched in one or other direction along the foliation, so that the length of their longer axes may be triple that of their shorter; but these ratios necessarily vary not only with the force of the stresses on any particular point, but with the crushing strength of the individual grain. The elongation of the pebble is frequently accompanied by fracture, represented by transverse or oblique cracks that have been subsequently infilled with quartz. In addition to these rents, the stretching has been attended by crushing, and the lenticles of quartz and felspar are bounded by tails of granulitic material representing the reconstruction of the pulverised portions of the pebbles. On the whole, the felspars have withstood the processes of deformation more effectively than the quartz.

In those beds in which coarser pebbles are scattered in a matrix of finer composition, the larger grains, although often elongated and granulitised at their boundaries, unmistakably betray their clastic origin, while the material in which they are embedded has been completely broken down. In such cases the matrix may still present a more or less granular appearance resulting from the original characters of its component grains, but recrystallisation has been so complete that even with the aid of the microscope no traces of its clastic condition can be discerned. It will be readily understood, therefore, that the still finer-textured bands, the flaggy quartz schists, formed out of fine sandstones, reveal no indication of clastic material, and that the sedimentary origin can only be inferred from their physical characters in the field, and especially from their relations to the more typical clastic beds with which they are associated.

While in the finer-textured quartz schists the nature of their stratification points clearly to a sedimentary origin, in the more pelitic zones, now represented by silvery mica schists, this is not so apparent. We find, however, that the composition of these pelitic zones corresponds to that of many soft micaceous seams that are interbedded with the grits, the sedimentary nature of which is obvious. Moreover, the gritty schists embrace types with every gradation of texture, and it is natural to conclude that the wider pelitic zones represent the argillaceous deposits or fine sandy shales of that group.

The Beinn Bheula Group also contains schists rich in albite that were first described in the Highlands by Mr. C. T. Clough in the *Geological Survey Memoir* on Cowal.* In this district, although their occurrence is known and a micro-slide has already been alluded to (3801), the bands have not been differentiated. These are usually micaceous or chloritic rocks charged with grains of small secondary albite which generally project from the

* 1897, pp. 39–45. See also "The Geology of Mid-Argyll," 1905, pp. 15–17.

weathered surface, and are of a clove or pale brown colour, which Mr. Clough suggests is due to inclusions. The albite grains are not deformed, and must consequently have orginated since the foliation was induced. Although often occurring in relative abundance, they are very minute and might be readily overlooked.

Dr. Teall has observed that rocks of a similar character have been described from the Continent and America, and that Dr. Credner states that hand specimens from these Argyllshire rocks can be exactly matched by specimens from Saxony. The reader who is interested in the comparison of these albite schists with their foreign equivalents, and the various localities of the latter, is referred to Dr. Teall's discussion of this subject in the "Geology of Cowal." * The albite gneisses in the Loch Lomond district have been described by Mr. E. H. Cunningham Craig, who has suggested their derivation from metamorphosed grits.†

In colour the Beinn Bheula Group ranges from grey to pale greenish hues, the latter being apparently due to the presence of chlorite.

STRUCTURES AND METAMORPHISM.

The study of this group of rocks reveals a remarkable array of superinduced structures that have been set up in response to earth stresses. On the most cursory examination of the ground it is immediately apparent that we are dealing with a series which has been crushed, folded and cleaved, but further investigation brings out the fact that many of these structures have been induced on rocks that had previously been subjected to similar deformation. Finally having traced these processes back, so far as their evidence has been preserved, we are yet in doubt whether we have arrived at the initial stages of deformation, or whether still older structures may have pre-existed and been obliterated by those that have followed.

Structural variations, other than those of sedimentation, depend on different degrees of metamorphism. Not only do the more massive beds offer greater resistance than the softer strata, but the processes of deformation often yield varying results in the same seam. A folded band suffers less deformation in the axes of the folds than in its limbs, while even the latter show characteristic distinctions, one limb usually having been stretched further than the other and showing a more advanced degree of metamorphism. Clastic structure may often be detected in the axis of a fold while over other portions of the band such evidence is wanting.

As already pointed out, the gneisses and pelitic mica schists are connected by intermediate rock types, according to the quantity of clastic material preserved, or to mineral variations determined not only by original composition but also by the degree of metamorphism. The perfection of the foliation obviously depends largely on the composition of the band. Thus the pelitic seams frequently represent a high degree of schistosity, being closely divided by foliation planes and literally packed with folia of mica capable of a minute fissile division. As the rock becomes more siliceous, these foliation planes

* Pp. 297, 298. † *Quart. Journ. Geol. Soc.*, 1904, vol. lx. p. 10.

gradually decrease, until in some of the gneisses, and especially the coarse gneissose grits, they may be separated by intervals of an eighth of an inch or even greater. In addition to structural characteristics depending upon the closeness of the foliation planes, there are distinctions marked by other characters of the latter. Mica may be abundantly or sparingly developed along the splitting planes, or the surfaces of the latter may be rough or smooth. In the coarser grits the foliation is more or less uneven, owing to the mica moulding itself on the irregular surfaces of the grains, but in some cases the grains have been so welded together that subsequent cleavage planes traverse them.

While the bedding planes have been contorted, the foliation planes are often even and straight; but, on the other hand, the latter have also frequently suffered contortion and strain-slip foliation set up parallel to the folding axes, and this secondary foliation may often be more pronounced than the earlier type. There is a marked difference in the field according as the foliation dip is steady or contorted, the latter giving rise to sections with a very irregular and gnarled character, which is still more pronounced when earlier quartz veins have shared in the later folding.

The schists have been thrown into a set of more or less isoclinal folds, the arches of which are frequently visible along the coast and in other rock sections. Normal folds are also often observed, but less commonly.

A most striking feature in the structure of the area is the occurrence of a great pseudo-anticline that has been traced across Cowal following a more or less south-westerly direction, from whence it emerges on the western side of Loch Fyne and traverses the central portion of Kintyre that lies within the area under description. This pseudo-anticline is not an anticline of bedding, as was originally supposed,* but rather of foliation and folding. Its characters have been described in the *Geological Survey Memoirs* on Cowal† and Mid-Argyll,‡ mainly by Mr. Clough, who was chiefly responsible for its investigation in that area. In the former publication will be found a diagram illustrating its structure, and the following quotations from Mr. Clough's description will present its salient characteristics. In most parts of the district "there is no particular line we can point to as the exact centre of the fold, for the schists on either side are excessively crumpled and with alternating dips for some distance." . . . "There is no doubt that this anticline is a true arch of an early foliation. Later foliations and other structures have been developed with it, as already described; but the most prominent foliation of the district, and an enormous amount of folding of the same age as this foliation, were already in existence before it, and were folded by it." . . . "It is clear, then, that the anticline cannot be a simple or exact anticline of bedding. It should rather be looked on as an anticline of the limbs and axes of the early folds which affect the bedding. To what extent it departs from being an anticline of bedding must depend on this early folding." In the discussion on its structures Mr. Clough advanced the hypothesis of "a

* T. F. Jamieson, "The Structure of the South-West Highlands of Scotland," *Quart. Journ. Geol. Soc.*, 1861, vol. xvii. p. 133.

† 1897, pp. 8, 9, 82–83, 84–87.

‡ 1905, pp. 72–84.

great folding of pre-anticline age which, roughly speaking, counterbalances the effect of the anticline," and "that there has been here an important early syncline."

In 1896* and 1903† the structure of the Cowal area was described by Mr. Peter MacNair, who dissented from Mr. Clough's conclusions. Mr. MacNair's hypothesis suggests a fan structure, according to which the dips in the anticlinal belt should approach the vertical instead of the horizontal, which is directly opposed to the facts as recorded by Mr. Clough, who has referred to this discordance of opinion in the "Geology of Mid-Argyll," p. 79. So far as this district of north-eastern Kintyre is concerned the facts agree with those recorded by Mr. Clough in Cowal, that the beds in the anticlinal belt are flatter than at its margins, from which the dip increases on either side towards the north-west and south-east respectively. The central or axial zone of the pseudo-anticline is here about a mile in breadth, that is to say, while within this zone it is impossible to adopt a line that would accurately represent the axis, on each side the limbs dip more or less steadily to the north-west or to the south-east. The rocks within the axial zone are highly folded throughout, but the axes of the folds may incline at all angles and in various directions.

As already alluded to, folding and foliation have been repeated. The earliest known foliation may either agree with the bedding or with the axial planes of the early folds. In some areas such foliation has been folded and crossed by strain-slip foliations, while the latest foldings and strain-slip foliations are connected with the movements that resulted in the great anticline of foliation, and they have slightly disrupted the earlier strain-slip foliations. The latter are accompanied by quartz veins, which are rare in those connected with the anticlinal movement. These veins have accordingly shared in the later disturbances, and bring out vividly the subsequent contortion to which the earlier structures have been subjected in the anticlinal zone.

As is the case in cleaved rocks, the foliation planes in traversing beds of diverse composition are deflected, so that in crossing from phyllitic to more quartzose bands the fissile planes are more steeply inclined to the bedding. Again, in alternations of pelitic and quartzose schists, the older structures may be entirely effaced in the former and yet be preserved in the latter, so that in such alternations not only is there a difference in composition but likewise in structure. As a rule the harder and more massive the rock the less is the foliation, and this interstratification of bands with varying fissility may often closely simulate false-bedding.

Quartz veins are very prevalent over the area and are frequently contorted and fractured, the crevices being infilled with secondary quartz. The veins are found both in the quartzose and micaceous schists, but they appear to predominate in the latter. Pegmatite veins‡ are rare, the felspar, which is usually of a reddish hue, playing a very

* "The Altered Clastic Rocks of the Southern Highlands," *Geol. Mag.*, 1896, pp. 167 and 211.

† "The Building of the Grampians," *Proceedings Roy. Phil. Soc. Glasgow*, 1903, vol. xxxiv. p. 160.

‡ The word pegmatite is here used to cover quartzo-felspathic veins of non-igneous origin.

subordinate part as compared with the quartz. Small strings of chloritic material frequently accompany the quartz veins, more especially on their margins, while occasionally an iron carbonate is represented. The felspar in the pegmatites in this area has not been analysed, but in the adjoining district of Cowal and in other portions of the Southern Highlands where this mineral has been determined, it has been found to be albite; and in this connection it may be remarked that albite pegmatites occur in the metamorphic area of South Devon. These albite pegmatites appear to be segregation veins, and are distinct from the quartz-microcline pegmatites that are associated with the granites.

When the Beinn Bheula group is traced to the north-east we find that the deformation steadily increases, the corresponding beds, for instance, at the head of Loch Fyne being in a more advanced metamorphic condition than in Kintyre. The differences noted are not so extreme, however, as in some other portions of the Highland sequence * developed in Argyllshire.

In considering the physical conditions under which the tectonic arrangement of the rocks and the regional metamorphism were superinduced, it is difficult to dissociate the larger structural features of the rock masses from those processes of mineral differentiation which may be regarded as interstitial. The direction of the folding axes and of the planes of foliation indicates that the dynamic stresses acted along a north-west and south-east direction, but at the present time it is uncertain from which of these points the stresses emanated, while it is even possible that compression may have proceeded from both directions. Notwithstanding that the degree of crystallisation points to a high temperature, and that minerals, such as garnets, have been found that are the common products of thermal action, we have discovered no evidence that suggests the existence of an underlying igneous magma. The petrological condition of these gneisses already described, appears to be analogous to that which would be likely to obtain at depths approaching the crushing points of those rocks. Notwithstanding the enormous plication which they have undergone, they have been singularly free from fracture, the faults which now fissure the area having been produced at periods long subsequent to the schistosity movements. Reversed faults or thrusts in which rock-flexure finally obtains relief are absent or rare. There is a like absence of the more interstitial type of brecciation represented by crush-conglomerates, although the latter are common in other parts of the Highland sequence, where metamorphism is at a minimum.† There appears, therefore, strong ground for the opinion that these rocks have been subjected to lateral compression at a depth in the earth's crust, below the zone of fracture, in which the pressure of the superincumbent mass has set up differential movements, resulting in a rearrangement of the mineral constituents. Although thermal action must have played a considerable part in the production of these crystalline schists, it is

* See J. B. Hill, "On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe," *Quart. Journ. Geol. Soc.*, 1899, vol. lv. p. 470.

† See J. B. Hill, "On the Crush-Conglomerates of Argyllshire," *Quart. Journ. Geol. Soc.*, 1901, vol. lvii. p. 313.

only as a necessary consequence of dynamic forces, which have liberated vast quantities of heat, in conjunction with the greater internal heat natural to such depths.

DISTRIBUTION AND FIELD RELATIONS.

The Beinn Bheula Group occupies the western shores of Loch Fyne from East Loch Tarbert to the southern margin of the map (29). Its boundary with the Green Beds is displaced by small transverse faults, but can still be represented by an almost straight line, running south-south-westerly from Tarbert Castle along the eastern slopes of the trough occupied by West Loch Tarbert. This series is entirely free from schistose igneous rocks.

As the shores of Loch Fyne dissect the group across the strike, the coast-line, which extends for about 7 miles, offers favourable facilities for its study. Commencing at the southern end of the section, we find gritty and quartzose schists of a highly metamorphic type with a very prominent set of foliation planes along which the rock splits, accompanied by well-developed strain-slip cleavage, which imparts an appearance resembling false-bedding. Along the main foliation planes greenish mica is developed extensively, in much greater abundance than in the beds of the anticlinal area further to the north, and this mineral is also characteristic of the strain-slip cleavage planes. There is a comparative regularity in the foliation planes, from their having suffered but little contortion from the movements that accompanied the production of the anticline. Amongst these rather quartzose beds more micaceous schists occur, and some zones must have been purely argillaceous. For instance, on the coast 1¼ mile north of Altagalvash there is a belt, 6 to 8 yds. in width, of bluish mica slate, and between this point and Altagalvash micaceous bands occur interstratified with the gritty and quartzose schists. The beds are here intensely metamorphosed, so that in the finer-textured bands the clastic character is practically obliterated, the grains being welded together into a solid siliceous mass; amongst these, however, coarser seams of grit preserve their granular character, as on the coast half a mile south of Altagalvash, where a gritty schist is made up of pebbles, of blue quartz and pink felspar, as large as peas. These coarse zones have been noted at other localities, as at Camas na Ceardaich. Besides the presence of these bands, there are interstratified seams exhibiting every variation in texture, so that there is rarely any difficulty in distinguishing foliation from bedding. Quartz veins are very common in this section, sharing in the contortion of the rocks in which they occur, but being more prominent in the pelitic than in the siliceous zones. At times felspar is associated with these veins, but as a rule in small amount.

In the section extending a mile northward from Altagalvash, some beds occur which are crumpled in the manner characteristic of the anticlinal belt, but the most prominent bands do not exhibit such an advanced degree of contortion. This facies, however, only extends for a mile, and is replaced to the north by contorted rocks of typical anticlinal structure, in which not only the interstratified bands, but the foliation planes also have shared in the folding. This

condition persists to Tarbert, and the rocks present a succession of schistose grits highly metamorphosed, with their grains flattened and elongated, here and there divided by zones that are less siliceous. Between the coarser grits on the one hand and the pelitic zones on the other there is every gradation of texture, coarse grits alternating with those of finer grain, and the latter with quartzose flagstones etc. But even with these interstratifications there is a remarkable uniformity of facies along the whole section: the even and more regular type of Altagalvash is no longer met with, and the rocks exhibit throughout a gnarled and corrugated aspect due to the prevalence of an extreme degree of contortion.

Inland sections present similar types, the various rock exposures and scars bringing out their structural characters vividly. It may be remarked, however, that about half a mile south-west of Altagalvash a fine-textured green schist rather recalls the Green Beds of the next group. The exposure, however, is small, and it cannot be affirmed with certainty that it is *in situ*.

While biotite is a common constituent in the anticlinal region, and from thence northwards to Tarbert, it does not appear to be so prominent in the less corrugated schists south of Altagalvash. Crystals of specular iron have been noted amongst the secondary minerals in the more micaceous zones, especially in the vicinity of Tarbert, and minute red garnets are likewise met with in the same locality, but very rarely. Some of the more striped siliceous bands can be seen to be made up of rows of quartz pebbles stretched and compressed into layers of solid quartz, with their clastic character destroyed. In other cases, where the rock is of a very compact type, indications of the clastic structure are sometimes yielded by the weathered surface.

In spite of the enormous amount of plication the average strike of the rocks can be determined as about north-north-east, but it is subject to many local deflections. It can be assumed with certainty that the beds are immeasurably thinner than a superficial examination might first suggest, and that the immense thickness ascribed to these schists by the early observers is based on data that are erroneous. In a region of such prevailing isoclinal folding the dips of the interstratified bands merely represent the inclination of the limbs of the isoclines, and where these limbs are parallel and consequently simulate a natural succession the strata have been repeated by constant reduplication. When such difficulties attend the interpretation of the succession where the original stratification is preserved, it can be readily grasped that in the more homogeneous deposits, in which structural planes are confined to cleavage and foliation, the problem is still more hopeless. Along the shores of Loch Fyne from the southern edge of the map to the appearance of the large basalt dyke at Rudha Grianain (about half a mile north of Camas na Ceardaich) the dip is most inconstant, but in the main lies between 30° and 45° to the south-east. Towards Lagganroaig it diminishes, dips of 25° and 15° being recorded in a similar direction; but such diminution is not uniform, for instance, whereas on the coast opposite Lagganroaig it is from 45° to 50°, about 300 yds. to the south it is from 25° to 30°. About 150 yds. to the north of the former locality, at Rudha Lagganroaig, it is 50°. And it is from this

point that the angle of the dip decreases more uniformly, changing from 40° to 25°, and for the distance of a third of a mile it is very low and undulating, the strata being at times horizontal; but where changing from that position, even but slightly, sloping towards the south-east. The contortions are such that a uniform passage from a high to a low dip cannot be observed. The first recorded dip to the north-west is at the east end of Fionn Bay and is steep, although the strata immediately to the southward are flat, or rolling, with some tendency to incline towards the south-east. At Carraig a' Chabaill on the west end of Fionn Bay, the strata are flat but rolling with a slight tendency to a north-westerly inclination, while a little to the south of Luib Dhubh * the dip, though variable, is generally towards the south-east. About 100 yds. further to the north the inclination is low towards the north-west, and from here northwards the prevailing dip is in the same direction. At Camas na Ban-tighearna it is 25°, but soon increases to 40° and 50°. The area in which the strata are either flat or rolling is about a mile in breadth, and nowhere along this zone can a definite position be assigned to the axis of "the anticline." From this zone northwards the average dip gradually increases, in the vicinity of Tarbert Castle being between 70° and 80° to the north-west, while still further north, but beyond the limits of the Beinn Bheula Group, it becomes vertical. The anticlinal zone has been traced by the writer for about 10 miles through the peninsula of Kintyre and beyond the limits of this sheet as far as Loch Romain, whence it was traced still further south by our colleague, the late Mr. R. G. Symes.

Near the top of the group and below the main Green Bed division, there are a few bands of Green Beds or of rocks allied to them. How far they may represent infolds of the main division or oncomings of the same type of sedimentation on slightly different stratigraphical positions is uncertain, but the marginal zone in which they occur scarcely ever extends beyond half a mile from the boundary, and is usually within half that distance. Localities in which such rocks have been noted are as follows: on the southern shore of East Loch Tarbert, about 200 yds. west of the Pier; in the Easan a' Chuthaich † Burn, about 1¼ mile distant from the base of the main zone; on the hillside east of Bardaravine, about one-third of a mile distant from the same margin; about a quarter of a mile north-west of Cnoc na Caorach and about the same distance from the boundary; while between that hill and the ruins of Cladh Bhride Chapel ‡ a few bands occur, the outermost of which is over half a mile distant from the main Green Bed Group. J. B. H.

* A quarter of a mile north-west of Fionn.
† A mile E.S.E. of Carnbuie. ‡ Half a mile north-east of Redhouse.

CHAPTER IV.

THE METAMORPHIC ROCKS OF THE MAINLAND.—(*Continued*)

II.—The Green Beds.

LITHOLOGICAL CHARACTERS.

The Beinn Bheula Group of schistose grits, granulitic gneisses and mica schists is succeeded to the north-west by another group containing similar schists, together with intercalated epidotic and chloritic bands. The subdivision is one which is well known in the Highland sequence, and has been described in the *Geological Survey Memoirs* under the name of Green Beds.

These rocks, owing to their more basic composition, differ so markedly from normal sediments that their inclusion among the former is a problem not easy to solve. It is possible, on the one hand, that they may have originated as volcanic ash, deposited on the sea floor with the sands and muds from which the associated grits and gneisses have been evolved; but the absence of volcanic lapilli throws doubt on this hypothesis, and it is important to notice that in this district where clastic structures are well preserved, the appearance of the Green Beds does not recall that of basic tuffs. Moreover, no contemporaneous lava flows have ever been recognised in association with them. On the other hand, it is possible that these bands, in common with the associated schists, were derived from the disintegration of an igneous complex, the more basic portions of which have furnished the materials for this abnormal deposit. Mr. Clough * has called attention to the striking resemblance, extending even to microscopic appearance, between these rocks and certain green grits of Lower Torridon age on the west side of the Sound of Skye that have been derived from the epidotised surfaces of the Lewisian Gneiss; so that it is clear that the Green Beds of the Highland sequence may also represent a phase of deposition unconnected with volcanic phenomena.

The Green Beds are not always sharply defined from the associated schistose grits and schists, but the two types often blend imperceptibly into one another, so that with the gradual diminution of the basic minerals the peculiar characteristics proportionately diminish; and in such cases the demarcation of the Green Bed type is necessarily an arbitrary distinction. Besides the grains of quartz and felspar that enter so largely into the composition of the associated Beinn Bheula types, these bands contain chlorite, epidote, biotite, iron ores, occasional calcite, and rarely hornblende and garnet. The

* "The Geology of Cowal," *Mem. Geol. Survey*, 1897, p. 36.

felspar consists of oligoclase and sometimes of albite, the latter being always a secondary mineral similar to that which enters into the composition of the albite schists. When garnet occurs in the Green Beds, it is likewise of secondary origin.

Three specimens of green schist have been examined microscopically, all containing biotite, chlorite, albite and quartz. Grains of epidote are abundant in two of the specimens (2914, 2915), hornblende occurs in one (2915), and calcite in another (3337). Dr. Teall observes that these specimens are similar to those described in the Cowal Memoir. In that publication he remarked * that "a special feature is the almost constant occurrence of granular epidote. Chlorite and a dark green or brown biotite are usually present, and a white mica in well developed plates is not uncommon."

The occurrence of hornblende in the Green Beds of Western Argyllshire is rare. It has been noticed in the micro-slide already referred to (2915), but its presence in Cowal has not been detected. In Glen Fyne, however, still further to the north-east, where the metamorphism is more advanced, the chloritic Green Beds have been converted into hornblende schists, and the mineral reconstruction has obliterated all traces of their original clastic condition, so that the rock cannot always be distinguished, even with the aid of the microscope, from the Dalradian basic intrusive rocks.† But in these cases the hornblendic constituent, which almost invariably takes the form of acicular actinolite, is clearly authigenic, whereas the hornblendic grains in the rock referred to, from near Tarbert, are represented by small rather ill-defined crystals associated with irregular patches of chlorite and grains of epidote which probably mark allothigenic constituents. In the Eastern Highlands our colleague, Mr. G. Barrow, has mapped Green Beds, in which hornblende needles occur in abundance associated with clastic grains of quartz and felspar as large as peas.

In the gritty varieties of the Tarbert area, the dominant mineral which forms the matrix is granulitic quartz, with occasional grains of felspar; the quartz occurs in aggregates and breaks up under polarised light into minute grains. Chlorite is common both in bright green flakes and in irregular patches. Epidote, in clusters of greenish crystalline grains, is also characteristic, and in some varieties enters very largely into the composition of the rock. Biotite, which is generally a very prominent mineral, occurs in broad greenish brown laminæ with characteristic ragged ends. The laminæ are often arranged in more or less clear parallelism. White mica is not so common, but a few colourless folia may occasionally be observed, while apatite and limonite have also been noticed. The rock in which hornblende occurs is a characteristic green bed containing a large amount of chlorite, biotite and epidote.

In the field these rocks are distinguished by their prevailing green colour which often assumes dark hues. They present a massive appearance, and stand out in striking contrast to the schists with which they are associated. In composition they range from

* "The Geology of Cowal," *Mem. Geol. Survey*, 1897, p. 297.

† See "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, pp. 18–20. See also E. H. Cunningham Craig, "Metamorphism in the Loch Lomond District," *Quart. Journ. Geol. Soc.*, 1904, vol. lx. p. 22.

quartzose and felspathic grits to beds of the finest material, the green colour being most pronounced in the latter, from the excess of chlorite and green mica, while the coarser bands present hues of pale yellowish green, evidently due to the presence of epidote. They pass by insensible gradations into normal mica schists and gneissose grits. Moreover, the finest-textured Green Beds closely resemble some of the highly deformed igneous rocks of the epidiorite group, and in a few instances they cannot be distinguished with certainty, but as a general rule the sedimentary structures of the former are preserved.

On the whole, the Green Beds appear to have resisted structural deformation more effectively than have the bands of the Beinn Bheula type, their massive condition having often protected them from some of the plication which adjoining bands of the latter type have undergone. They also exhibit comparatively few quartz veins, and such as do occur are often to some extent charged with epidote. The Green Beds display more rounded outlines and less rugged surfaces than the associated schistose bands, and in their mode of weathering rather approach that of the massive epidiorites; further, their decomposition produces a richer soil and supports a vegetation more akin to that of the basalts and hornblende schists than to that of the Beinn Bheula schists. The finer beds often decompose to a soft greenish earthy material, amongst which the tiny spangles of glistening mica are conspicuous.

DISTRIBUTION AND FIELD RELATIONS.

The Green Beds are widely distributed in a band between the Beinn Bheula Group and the first oncoming of the Loch Tay Limestone. While on Sheet 29 the latter horizon has been adopted as the north-western limit of the main zone, in that part of northern Cowal included in Sheet 37 it has been taken somewhat farther to the south-east, and the band which thus separates it from the Loch Tay Limestone has been termed the Glen Sluan Group. Similarly to the south-west, in Sheet 28, a small band of the Glen Sluan Group has been separated on the map. The Green Beds, however, although attaining a great development in the band coloured as such on the map, are not entirely restricted to it. They are represented to the south-east within the Beinn Bheula Group, while they are still more frequent in the Glen Sluan Group to the north-west. The boundary of the main group with the Beinn Bheula Group extends from Sgeir Port a' Ghuail, on Loch Fyne, to Grassfield, on the southern edge of Sheet 28, with an approximate direction of south-south-west, passing in its course Tarbert Castle, the Abhainn Achachoish, Bardaravine and Arivore Farm. The Loch Tay Limestone, taken as its opposite margin in Sheet 29, extends from Barmore on Loch Fyne to Carnbuie on West Loch Tarbert. From this locality the boundary extends to the southern margin of Sheet 28, passing near Tigh-na-Coille, Achnancarranan, Redhouse and Whitehouse. The band thus demarcated has an average breadth from half to three-quarters of a mile within Sheet 29, and somewhat less within Sheet 28. It was traced by the writer from Loch Fyne to Achnancarranan, and beyond that locality by Messrs. Symes and Bailey. Along the

former part of its course there is a comparatively well-marked south-eastern limit to the zone, the mapping of which has been the means of detecting several faults which otherwise would have escaped observation. They have an average north-westerly direction and between Loch Fyne and Achnancarranan heave the Green Beds boundary to the south-east in a series of steps.

Although we are able to adopt a satisfactory boundary-line to the south-south-east, its opposite margin cannot be so precisely defined, and for a great part of its course it has been found convenient to take it, as already remarked, at the Loch Tay Limestone. Even within the limits of the differentiated zone the Green Beds represent less than a moiety of the strata, while beyond the horizon of the limestone their proportions are considerably less. But although diminishing in quantity towards the north-west they have a wide geological range, some of them occurring in rocks that we correlate with the Ardrishaig Group.*

An excellent section of these beds is afforded by the coast of Loch Fyne between Port a' Ghuail and Port nan Seilisdeir,† where bands ranging from the coarse pebbly type to the fine-textured varieties are seen dipping at very high angles to the north-west, often with a close approach to the vertical, and markedly contorted. Between that coast-line and Tarbert they are frequently exposed along the rocky slopes, while at the latter locality they are very conspicuous and have been extensively wrought for building purposes. Near the southern outskirts of the town they are vertical. In the direction of West Tarbert they are considerably developed on the craggy hillside, while in the Achachoish Burn excellent dip sections are exhibited where inclinations of 75° to the north-north-west have been recorded. They are likewise exposed in the stream at Bardaravine, and occupy much of the wooded tract between Achnancarranan and Cladh Bhride.‡ Towards the southern margin of Sheet 28 the zone is largely concealed beneath boulder clay, but typical bands are exposed near Redhouse and Grassfield, and also about half a mile west of the latter locality. The Green Beds on the north-west side of the main zone occur within the Stonefield Schists and the Erins Quartzite, and they will be further alluded to in the descriptions of those rock groups.

In structure these beds do not differ greatly from those of the Beinn Bheula Group. As we recede from the anticline of foliation that traverses Kintyre the dip becomes steeper, until it finally becomes vertical in the Green Beds of Tarbert. Both the bedding and foliation have shared in the later plication brought about by the anticlinal movements, and the sections exhibit a high degree of contortion and minor crumpling; but, as already observed, the Green Beds on the whole have suffered less deformation than the schists with which they are intercalated.

This main group of Green Beds is traversed by but few schistose igneous rocks: a large epidiorite occurs, however, on Barmore Island.

* See also "The Geology of Cowal," *Mem. Geol. Survey*, 1897, p. 37.
† About a third of a mile N.N.W. of the last locality.
‡ Half a mile north-east of Redhouse.

III.—The Glen Sluan Schists.

In the description of the Green Beds (p. 24) it was pointed out that whereas in Sheet 29 the north-west boundary of the group has been taken at the Loch Tay Limestone, in the adjoining Sheets (28 and 37) this boundary has been drawn somewhat to the south-east of that limestone. The intervening band is known as the Glen Sluan Schists, from a locality in the Strachur district of Upper Loch Fyne. This series, which occupies a narrow band skirting West Loch Tarbert, is only distinguished from the main Green Bed zone by the very much smaller proportion of green bed material in it. Green Beds are nevertheless fairly represented along the band; they may be observed in the wood between Achadacaie and Tigh-na-Coille, and a few meagre examples occur between Ceann-na-craige and the southern margin of the map (28). The rocks which enter mainly into the composition of the group are quartzo-micaceous and gritty schists precisely similar in their lithological structural and metamorphic characters to those of the Beinn Bheula Group. In spite of marked contortion they have a prevailing steep inclination to the north-north-west, dips as high as 70° being common. The schistose igneous rocks enclosed within the group are represented by a few epidiorite outcrops, such as those in the vicinity of Sunnyside Cottage, between Carnbuie and Tigh-na-coille.

IV.—The Loch Tay Limestone.

Lithological characters.

The Glen Sluan Schists and Green Beds are succeeded to the north-west by a well-marked limestone that has been traced right across the Highlands, and forms one of the most distinctive members of the Dalradian sequence. From Loch Tay it passes south-westward to Cowal, and reappears on the western shores of Loch Fyne opposite the island of Barmore. From thence its course may be traced to the sea along the slopes of the basin occupied by West Loch Tarbert. Its prevailing colour is blue to grey, but paler hues are often represented and green tints are not uncommon, especially in the vicinity of epidiorite intrusions. Impure varieties passing into quartzose and micaceous schists, both calcareous, are of frequent occurrence, but are usually much thinner than the main band. It is completely crystalline, and the bedding is well preserved in layers ranging from an inch to a foot in thickness. White mica, lying along the foliation planes, is frequently abundant, while some of the calcite grains appear to contain carbonaceous material and impart darker hues to the rock.

The limestone is commonly associated with epidiorite sills, often strictly parallel to the bedding; in other cases, however, they cross the stratification and produce contact alteration in the limestone: in fact, their intrusive origin is clear where the margins are sufficiently exposed for detailed examination. There is sometimes the closest interbanding of the two rocks, which is regarded in general as the result of constant reduplication by folding.

DISTRIBUTION AND FIELD RELATIONS.

The Loch Tay Limestone is represented by parallel bands of limestone which appear to mark repetition by folding. It is seen on the coast of Loch Fyne at South Bay, opposite Barmore Island, where it succeeds greyish pebbly schists. The rock is of a bluish colour, very compact, with bedding vertical and a strike of N. 30° E. The crop of the main band is divided by an epidiorite sill into two parts, the south-eastern one being from 25 to 30 yds. broad. The north-western portion is succeeded on the north-west by another band of epidiorite, probably merely a folded portion of that on the south-east. To the north of the main band some impure limestone or calcareous schist is represented. The limestone and associated epidiorite or hornblende schist may be traced across the hillside nearly to the head of West Loch Tarbert. It may then be followed past Eascaird to Carnbuie, where it strikes the coast-line, and its close interbanding with the hornblende schist is conspicuous. This may also be studied in a quarry at Carnbuie, and on the coast below Rhu, and to the east of Rhu Point. A section on the shore about half a mile south-west of Carnbuie presents the following sequence from west to east :—

	Ft.
Limestone	12
Quartz schist	12
Limestone	1
Hornblende schist	3
Limestone	3
Hornblende schist	2
Limestone	1
Hornblende schist	3
Limestone	20

V.—The Stonefield Schists.

This group occupies a zone nearly a mile in breadth between the Loch Tay Limestone and the Erins Quartzite. Like the Glen Sluan and Beinn Bheula Schists it consists essentially of granulitic gneisses and schistose grits, but quartzite and quartz schist reach a greater development than in these groups. Limestone and calcareous schist also occur, but these are possibly infolds of the Loch Tay Limestone. A few bands of chlorite schist are met with of Green Bed type, but they are usually fine-grained and occupy a very subordinate position. Sills of epidiorite are strongly represented in two parallel belts accompanying the limestone outcrops. Garnets have been exceptionally observed in the inland exposures, and serve to accentuate the correlation of the Stonefield Schists with the garnetiferous mica schists further to the north-east.

The best section across the group is afforded by the coast-line of Loch Fyne between South Bay and Port an Dunain. Barmore Island is not included in this section, being isolated by a fault. Proceeding northwards from the limestone and associated epidiorite at the South Bay, hard quartzose mica schists are met with, mainly of fine texture and considerably puckered, and containing much biotite as well as the pale greenish mica which occupies the foliation planes. On the

shores of North Bay these schists are calcareous, and the more siliceous beds have a less pronounced green hue than the more micaceous. Two hundred yards from the head of the North Bay, although still calcareous, they assume a coarser texture and are of the nature of schistose grits, but are almost immediately replaced by fine-textured green calcareous schist. The latter, however, occupies but a narrow band and is succeeded, at a quarter of a mile from the head of the bay, by compact flaggy quartz schists, which are interbedded with a few thin limestones, ranging from 1 to 6 ft. in thickness. Coarse pebbly grits also occur which are in part calcareous. They consist of very fine laminæ of coarser and finer material, but the pebbly structure is distinctly seen on the weathered surfaces of the coarser bands; amongst the grains blue quartz is very conspicuous, while elongated fragments of red felspar are also present. Most of the pebbly beds of this group are, however, less compact and exhibit characteristic gnarled structure. Beyond this are a few seams of epidiorite amongst highly-contorted siliceous schists, differing but slightly, if at all, from the beds of the Erins Quartzite division, the margin of which has been drawn almost immediately to the north.

Within this group, as before mentioned, is a belt of limestones, well developed at Ashens, which may represent the Loch Tay Limestone repeated by folding. On the other hand, it is possible that the limestones here, although of the same general character as the Loch Tay bed immediately following the Glen Sluan Schists, may belong to a higher horizon, and they are represented on the coast of Loch Fyne, to the south of Port an Dunain, by a few bands ranging up to 6 ft. in breadth. At Ashens the limestone outcrop exceeds 20 yds. in width and is flanked on either margin by calcareous schist. It is again seen at the small lochan three-quarters of a mile further south-west and is there associated with epidiorite. Entering Sheet 28 it is represented by two parallel bands from 20 to 30 ft. in breadth, and still further south-west is seen at Cuil-na-seamraig, Barabhalla and other localities along that line. A typical specimen obtained from the quarry at Ashens is a medium-grained, bluish grey crystalline limestone containing white mica and some pyrite, the former mineral being biaxial with an optic axial angle of about 42°. Dr. Teall observes that under the microscope (3344) the rock is seen to contain also crystals and grains of quartz with black opaque inclusions which are probably carbonaceous. The quartz does not represent clastic grains, but has been developed *in situ*.

In describing the Beinn Bheula, Green Beds, and Glen Sluan Groups, it was pointed out that the average dip of the folded strata and planes of foliation was steadily increasing from the pseudo-anticline of Kintyre in a north-westerly direction. The high angle of dip attains its culminating point within this division and the neighbouring portion of the quartzite indicated upon the map to the north-west: the inclination not only reaches the vertical but actually bends over in a contrary direction, steeply towards the south-east. A line along West Loch Tarbert and from the head of that fiord to Stonefield, marks the division between the strata that are thus highly inclined in contrary directions. This peculiar structure, as may be seen from the map, does not extend for more than about 3

miles down the west side of West Loch Tarbert. South of this limit the inclination of the strata is almost invariably to the north-west.

There is no sharp division between the Stonefield Schists and the Erins Quartzite Group. While the latter mainly consists of quartzite and siliceous schist, these types are also represented in the Stonefield division; but between Loch Fyne and the upper reaches of West Loch Tarbert, they usually occupy a subordinate position. Towards the south-west, however, they occur in such abundance that beyond the Abhainn Ghillean Burn the mutual boundary of the Stonefield and Erins Groups can no longer be traced, and the line connecting that stream with West Loch Tarbert is only of value as a colourist's boundary defining the approximate limits of the quartzite without reference to stratigraphical considerations.

Even in the area where it can be more or less readily differentiated, the Stonefield Group exhibits fundamental distinctions from its normal characteristics in its passage across the Highlands. While in this region it is largely composed of gritty and quartzose schists similar to the Glen Sluan and Beinn Bheula divisions, in northern Cowal it is represented by the much more pelitic garnetiferous mica schists. In the description of the Cowal area* it has been remarked that regional metamorphism is increasing towards the north-east, and that this is especially shown by the garnetiferous mica schists. Towards the south-west, conversely, the metamorphism diminishes, and the conspicuously garnetiferous character of the zone fails before reaching the coast of Lower Loch Fyne, although microscopic garnets have occasionally been recognised in that part of Cowal. Likewise on the western side of Loch Fyne, the scanty garnets detected in the Stonefield group cannot compare with those of the more north-eastern areas. But apart from rarity of this special mineral, there is likewise a change in the lithological facies of the group in its south-westerly course. Instead of being largely a pelitic series, it is represented by siliceous material, and in this part of Argyllshire is made up of schistose grits, quartzose flagstones and quartzose mica schists. This increase of silica in the south-west is also shared by the neighbouring division of the Ardrishaig Series which adjoins it to the north-west, as was pointed out in "The Geology of Mid-Argyll."† As the result of this increase the distinctive stratigraphical features are masked, so that the Stonefield group that represents the garnetiferous mica schists of Cowal merges into the Erins Quartzite, which, in part at least and as the writer believes entirely, must be grouped with the siliceous members of the Ardrishaig division. J. B. H.

* See "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, pp. 72–83.
† *Mem. Geol. Survey*, 1905, pp. 34 and 35.

CHAPTER V.

THE METAMORPHIC ROCKS OF THE MAINLAND.—(*Continued*)

VI.—The Erins Quartzite.

This band, which succeeds the Stonefield Schists, occupies a broad belt extending to the north-west as far as a line connecting Brenfield Point on Loch Fyne with Kilberry on the Sound of Jura. Its central portion is traversed by a narrow band of phyllite lying between Stronchullin and Loch Stornoway and flanked in the southern extension by another parallel belt which lies some little distance to the north-west. Along the strike to the north-east the quartzite belt re-emerges from the sea near the eastern entrance of Loch Gilp, and occupies the coastal tract extending to the northern edge of Sheet 29, between Culard Rudha and West Kames. In the following descriptions the development of the group to the west of Loch Gilp will be described before treating of the separate area to the north-east.

ERINS QUARTZITE, SOUTH-EAST OF STRONCHULLIN PHYLLITE BAND.

Erins District.—This area is situated in the parish of South Knapdale and lies entirely within Sheet 29, extending from the coast of Loch Fyne to the western edge of the map. It is bounded on the north-west by the Stronchullin Phyllites, and on the south-east by the margin of the Stonefield Schists.

The shores of Loch Fyne dissect this portion of the band, and a brief description of the coastal margin will be presented.

At Port an Dunain very siliceous schists occur, which are much contorted, and a little further north, on the south side of the first epidiorite band shown on the map, these rocks are nearly vertical. On the other side of that epidiorite sill, the beds still show much contortion and are of a highly siliceous or quartzite type; but in spite of this compactness the gritty structure is apparent. A little farther north a belt of closely contiguous epidiorite sills, shown by a single outcrop on the map, is bounded on the south by quartzite, which together with quartzite schist occupies the intervals between the intrusions. This is succeeded by greenish grey quartzite schist and pebbly schists of the same hue, veined with quartz and still showing much contortion, with the folded strata inclining steeply to the south-east; the clastic grains are coarse and include much blue quartz, together with elongated fragments of felspar, some of which form lenses half an inch in length. Phyllitic material is represented by narrow divisions of silvery grey mica schist, but is quite subordinate. These strata are immediately succeeded by pebbly green schist

evidently related to the Green Bed type. Between the latter and the mouth of the Allt na Beiste * are flaggy quartzites, quartz schists and well-pronounced grit beds, together with a few narrow seams of impure limestone; the limbs of the folds have a general steep south-easterly inclination, except at the mouth of the stream, where they reach the vertical and in places incline even to the north-west. To the north of the burn are gritty schists with calcareous grits and some more compact strong gritty quartzites. Most of the beds, however, are intermediate in character between grit and quartzite, and phyllite is still scarcely represented. To the north of Eilean an Dùnain some compact quartzites occur amongst gnarled quartzose schists of the same character as the Stonefield schists. The latter type is also seen on the coast half a mile further to the north, where quartzose schists and quartzose mica schists are arranged in fine-textured laminations, in which the clastic structure is scarcely apparent; these are interstratified, however, with strong schistose grits, some of which pass over into quartzite. The crumpling and contortion is still pronounced, while the folded strata incline to the north-west, usually at a high angle. In the vicinty of Ard nan Ron, † crumpled quartzites and siliceous schists of a highly compact nature occur, in which, although traces of blue pebbles are seen, the clastic structure is nevertheless almost obliterated. At Rudha Dubh, ‡ although the strata are highly contorted, the prevalent inclination is still to the north-west, and the rock consists of siliceous schist with thin calcareous seams, intermixed with hard crumpled mica schist. The latter is mainly quartzose, but some subordinate dark lead-coloured phyllite is also present. Further north, at Sloc nam Fearna, the strata are contorted and made up of quartzose schists with narrow partings of silvery mica schist. Between the marine terraces of Milmore and Mounterins, there is a continuous section in which quartzites and highly compact siliceous schists are typically developed. The alternations are sufficiently sharp for the bedding planes to be readily identified, but contortion is still pronounced. Except in the extreme north, however, there is no difficulty in seeing that the general inclination is to the north-west. In that locality, while the undulations are approaching the horizontal, the contortion is such that the prevailing inclination cannot be estimated. These highly siliceous beds are interstratified with hard quartzose mica schists and some very thin greenish silvery mica schists. The whole section, however, presents a high degree of metamorphism and violent contortion, and it is probable that the pelitic material has been considerably attenuated by the processes of deformation, while the quartzite bands have been better enabled to preserve their thickness. The siliceous members, notwithstanding, have been so closely compressed that the clastic structure is seldom conspicuous, although in some bands the pebbles may be readily distinguished. Similarly, the difference in weathering between the quartzites and quartzose mica schists are not so pronounced as in the less metamorphic area to the north. Instead of the angular edges so common amongst the

* The stream which meets the coast south of Eilean an Dùnain.

† The prominent little headland midway between Eilean an Dùnain and Sloc nam Fearna.

‡ About 300 yds. further to the north.

quartzites in the less altered areas, there is a tendency for the siliceous bands in this section to present curved surfaces. Thin calcareous seams occur amongst the quartzite, as already observed in the section further south. Moreover, biotite flakes are present, and are frequently arranged in clusters on the foliation planes.

Between Mounterins and Artilligan, the limbs of isoclines are themselves thrown into obvious anticlines and synclines, so that the general inclination is no longer in a north-west direction, but exhibits repeated variations between this and the south-east. The rocks are similar lithologically to those further south, consisting of massive quartzites and hard silvery quartzose mica schist. Instead of the pale grey hues, however, so prevalent hitherto, some of the siliceous bands are of a very pale greenish tint, a colour also observed in the section between Artilligan and the Artilligan Burn. A little south of that stream the quartzites are intermixed with thin bands of limestone of the Ardrishaig type, about a foot in width, which effervesce freely with cold hydrochloric acid; they are associated with green calcareous mica schist, also similar to that of the Ardrishaig Phyllites in areas of corresponding metamorphism. From Artilligan to the Artilligan Burn, the prevailing inclination of the contorted strata is to the north-west. A little to the north of that stream it inclines to the south-east with perhaps an average angle of 25°; towards Nead an Fhithich,* however, it again points to the north-west, and continues in that direction for a third of a mile further to the north, where inclinations have been noted varying from 10° to 45°. Then for a short distance the strata are again inclined at an angle of about 25° to the south-east, but this is almost immediately replaced by north-westerly dips, which continue to the raised beaches at the south of Tigh-an-Droighinn Bàgh, with angles ranging from 50° to 40° for about 300 yds. and from 30° to 20° for the remainder of the section. The lithological types between the Artilligan Burn and Allt Corlaraiche† are repetitions of those seen further south, consisting mainly of quartzite and compact quartz schist, occasionally with gritty structure, and sometimes enclosing lenticles of dark lead-coloured phyllitic material; fissile calcareous schist, highly metamorphosed and displaying greyish green hues, is also intercalated in the group.

At Rudh' á Mhinidhe Mòr,‡ pale greyish green quartz schists preponderate over quartzite and exhibit still a high degree of metamorphism. At Rudh' á Mhinidhe Beag, 300 yds. further on, quartzose bands are interstratified with hard silvery phyllites, the whole much crumpled, but presenting a very homogeneous appearance as the result of the advanced type of metamorphism. Towards the end of the section, however, the weathering is more like that of the less metamorphic area further north, showing thin bedded quartzites, with puckered quartzose and pelitic schists; but some of the silvery mica schists are still studded with flakes of biotite, in part forming clusters with blades half an inch in length. The terraces of Stronchullin interfere with the continuity of the rock section for about half a mile, but it reappears at Creagan Beag.

* About a third of a mile north of the mouth of the Artilligan Burn.
† About three-quarters of a mile further north.
‡ A little more than half a mile south-east of the mouth of the Stronchullin Burn.

The strata here exposed, with north-westerly dips ranging from 20° to 30,° are practically a repetition of those last described and consist of calcareous quartzites, fissile quartz schists and silvery phyllites, the latter carrying secondary biotite, but possibly in less quantity than in the previous section. Although the lithological types on either side of the terraces are identical, the degree of metamorphism apparently diminishes in the northern outcrop. North of the Creagan Beag exposures there is a small gap representing the Stronchullin Phyllite belt. Beyond this the outcrops extending to the southern edge of the marine terraces of Inverneil, although representing precisely similar strata, lie within the Inverneil district that will be separately described.

A specimen from Erins was sliced for miscroscopic examination (3336) and described by Dr. Teall as a platy quartz schist, essentially composed of quartz and two micas with felspar and garnet as accessories. The micas occur in distinct plates, their basal planes being parallel with the planes of schistosity, and the structure is that of a true crystalline schist.

The inland tract, extending from Loch Fyne to the western margin of the map (29), presents features corresponding to those of the coast section just described. The rocks give rise to rugged and precipitous slopes that often attain a level of 1000 ft. within a mile from Loch Fyne. In the Artilligan Burn, a little west of its northern angle, a limestone that passes into calcareous schist forms a band from 5 to 6 ft. in width, and is somewhat larger than the limestone seams seen on the coast, which are so narrow that they have not been shown on the map. Another outcrop of blue crystalline limestone, of which 2 to 4 ft. are exposed, may be seen in the course of a south-east flowing burn, three-quarters of a mile W.N.W. of Stonefield. Representatives of the Green Bed type are rare, but have been noted at the following localities, namely, a quarter of a mile N.N.W. of Ashens and three-quarters of a mile west of the same place in the burn just south of the track. Epidiorite sills are especially conspicuous towards the south-eastern boundary, where they illustrate the folding of the area. One outcrop of these intrusions extends almost from the coast to the western edge of the map. They occur likewise in some profusion between Artilligan and Srondoire.

Continuation of Erins District to the Southern Margin of Sheet 28.—This tract of quartzite, as coloured upon the map, contains several outcrops of limestone, in regard to which two distinct interpretations may be entertained. On the one hand, the boundary drawn upon the map between the Stonefield Schists and Erins Quartzite is so indefinite south-west of the Abhainn Ghillean, that it loses much of its stratigraphical value. The limestone outcrops, which appear to the south of this point in the eastern part of the belt allocated to the quartzite, may, therefore, be folded representatives of those occurring in the Stonefield Schist belt. On the other hand, they may occupy a distinct horizon in the Erins Quartzite Group, and, although closely agreeing in type, may signify recurrence of similar conditions in the original sedimentation. Mr. Bailey inclines to the latter

view, whereas the writer considers that they are repetitions by folding.

Limestones.—A brief description of the limestone outcrops falling within the district under consideration will now be given. Midway between Lochan Liath and West Loch Tarbert there is a band, from 25 to 30 yds. in width, which extends past Torrantuirc and is seen near the coast amid the alluvium to the south-west. It contains an exceptionally pure bed, from 20 to 30 ft. thick, that has been quarried and is said to produce lime of exceptional purity. It is a highly crystalline marble, banded with alternating light blue and white tints. Pyrites is scattered through the mass, which is veined with calcite, mica and quartz: quartz is also disseminated in the rock. A parallel outcrop, 30 yds. in width, reaches the shore a quarter of a mile further east, and between these two seams a subordinate band, 6 ft. in width, is seen at the foot-bridge at the mouth of the Torrantuirc Burn.

It will be seen that if these outcrops belong to the Ashens limestone belt, the latter in its passage to the south-west is gradually extending in width owing to more repeated folding, so that the various bands are arranged *en echelon*. The limestone to the west of Lochan Liath evidently represents a wing of that formation, but as it frequently lies flatter it often gives rise to wide outcrops. The most north-easterly exposure of this band is seen in Eas a' Chais, about two-thirds of a mile north of Lochan Liath, where its greatest width is about 60 yds., and it is crossed by a few basalt dykes. In the lower part of the burn it is about 30 ft. wide, but at Achalach its outcrop expands to about 250 yds., including seams of interfolded mica schist. The bedding here dips about 20° to 25° N.N.W., and the swelling of the outcrop is the result of plication. It soon resolves itself into a narrow band which passes along the hollow to the west of the old fort. J. B. H.

Two minor outcrops of impure limestone are shown on the map on either side of Gleann Fithich. The more southerly one is a brown sandy limestone and occurs beside a band of epidiorite too small to represent on the one-inch map. Probably this limestone extends for some little distance to the south, since an exposure of similar type is found along the same strike in Glen Achanaglachach. Another seam of impure limestone, on a more south-easterly line, outcrops at Creag-eanntagaich.

All these lie north-west of the important bed of pure blue or grey limestone which was traced to the west of the old fort. This limestone is lost sight of for a little, where outcrops of epidiorite appear to bar the way. On reappearing to the south of the farm road to Creag-eanntagaich, two bands instead of one are found. This is suggestive of reduplication by folding. The two bands can be followed down into Glen Achanaglachach. They appear to be shifted at this juncture by a fault running down the glen.

To the south, near Craig Lodge, two closely approximated outcrops of the usual pure blue-grey, medium-grained crystalline limestone are well exposed. Probably these represent, not the continuation of the bands last described, but rather that of the

Torran-tuirc belt, shifted in a little bit by the Glen Achanaglachach fault. From Craig Lodge these bands can be traced at intervals to the seashore, one of them being well exposed in a quarry at the turn of the road. White bands here alternate with the grey.

The northern limestone, which was traced in two bands down into Glen Achanaglachach, is not exposed again for three-quarters of a mile. Even then at first only a single band can be detected. To the south-west, however, the outcrop is largely augmented, and, by the side of the high road in the neighbourhood of Kilanaish, there is a fine display of blue-grey limestone, in outcrops alternating several times with bands of epidiorite. It is probable that the details of this irregular outcrop are largely determined by folding. From Kilanaish a single band can be traced to the sea, reaching it at the head of Achadh-Chaorunn Bay, in the one-inch map to the south (Sheet 20). E. B. B.

Quartzite etc., South-West to Car Mòr.—As already observed, to the south-west of the Abhainn Ghillean, part of the Stonefield Schists has been coloured with the Erins Quartzite, on account of the increasing siliceous nature of the Stonefield Schists in this direction.

Notwithstanding, however, the somewhat similar lithological facies presented by the two groups in the area through which no stratigraphical boundary has been drawn, it is possible to define broadly the limit of a marginal zone in the portion coloured as quartzite, which in its gritty character more closely approaches the type of the Stonefield Schists. In the description of the latter group it has been shown that its dominant feature is its pebbly character, whereas the adjoining Erins Quartzite division is of finer texture with only subordinate grit bands. Various parallel limestone outcrops on the two sides of Lochan Liath are situated in a zone of schists with a prevailing pebbly structure. It has been observed that, to the south-west of the Abhainn Ghillean, the limestone outcrops increase in number in a manner which we regard as the result of folding, so that they extend still further to the west into the tract that has been coloured as quartzite. Now the belt in which these limestones occur contains as great a preponderance of grit bands as do the Stonefield Schists to the north-east, so that the limestone belt, which beyond the Abhainn Ghillean bulges to the west, is flanked on its outer margin by a zone of grits which shares in that bend. Thus, commencing at the eastern margin of the map, we find a marked development of gritty schists forming the crags of Cruach Gar-dhoire and overlooking the river for half a mile to the south-west. They occupy an horizon about half a mile in width adjoining the Ashens limestone belt. Beyond the Abhainn Ghillean these grits swing to the westward past the southern slopes of Cruach Chaorunn Beaga, and from thence to the south-west to Gleann Fithich. They thus enclose the zone, extending westward from West Loch Tarbert, in which the limestone outcrops occur. The edge of this grit zone extends a quarter of a mile beyond the most westerly limestone outcrop in Eas a' Chais, but considerably more than that distance in the curve below Cruach Chaorunn Beaga. Probably, therefore, the western margin of this pebbly zone

represents approximately the boundary between the Stonefield and Erins divisions.

The increase in the siliceous nature of the strata in this area, as compared with those of Loch Fyne, is also accompanied by an increase in the coarseness of the stratification; for, whereas in the latter district individual bands exceptionally attain a width of 5 or 6 ft., in this region a quartzite band has been quarried, adjoining the roadside a quarter of a mile S.S.E. of Lochan Liath, of about 20 ft. in thickness.

As in the sections on the Knapdale shores of Loch Fyne, seams of coarse texture have been occasionally noticed. To the north-east of Lochan Liath, pebbles larger than peas are found amongst finer material in a thin bed, and at the eastern base of Cruach Chaorunn Beaga there is a band, about 3 ft. in width, with pebbles of a similar size. The ridge midway between Cruach Chaorunn Beaga and the angle of the high road contains large pebbly bands, in which grains of blue and white quartz and subordinate felspar attain the same dimensions. This ridge also displays quartz veins that share in the contortion of the strata. In places there is no sharp distinction between the vein and the adjacent siliceous rock, the former passing insensibly along the bedding planes into a hornstone type which, further on, again gives place to white quartz.

As already mentioned, in the tract where the limestones occur, the strata are mainly composed of gritty schists in which typical quartzites, quartz schists and quartzose mica schists are subordinate, but in the area beyond, the rocks are of the latter types, grit bands being more rarely noted. On the east side of Blar nan Con pebbly beds occur, in some of which the individual grains are of the size of peas, and there is a similar band on approximately the same horizon one-third of a mile south-east of Loch Chaorunn. Coarse grit seams have likewise been mapped half a mile east of Cruach Gille Bheagain. Further to the north siliceous grit has been noted at the edge of the map, east of Meall Mòr.

Rocks allied to the Green Beds are rare in this tract, but have been noted between Traigh Bhan and the next indentation of the coast to the south-west.

The folding over the area, to the north-east of Car Mòr, is most pronounced. The limbs of the folds incline at all angles, horizontal and vertical strata sharply succeeding one another, while the dip is frequently in contrary directions within very short distances. A similar phase of plication has been described on the section along the coast of Loch Fyne. The strata lying to the north of Loch Chaorunn have, in spite of these irregular plications, a general north-westerly inclination. On the other hand, those strata lying to the east of a line connecting that loch with Lochan Liath show prevailing south-easterly inclinations, while in the still larger region situated west of that line contrary dips, to north-west and south-east, seem about equally apportioned.

Epidiorite intrusions, represented by parallel sills, are a constant feature in the area; but in the marginal zone, about a mile in width, between Forest and Loch Caoi-rain, their occurrence is exceptional. The largest of these sills, which traverses the centre of the district between Loch Chaorunn and Ant-aonach, has been traced for nearly

4 miles, and, in common with some of the other intrusions, reflects the isoclinal structure of the area. J. B. H.

Quartzite etc., South-West from Car Mòr.—Fine-grained white quartzitic and quartz schists are the prevailing types in this district. Bands of grey pelitic schist, also, not infrequently occur interbedded with the quartzitic rocks, and are, in fact, very abundant for a quarter of a mile east of the boundary taken for the Stronchullin Phyllite belt. Pebbles are rare, but have been noticed at several points and are probably more characteristic in the portion of the outcrop containing the limestone bands than elsewhere. Pebbly quartzites with thin beds of limestone, recalling at once the Ardnoe type of the Loch Awe Group, are well exposed on the shore near the basalt dyke a mile south-west of Torrantuirc. Very pebbly beds may also be seen at the old fort above the Ferry; and again, where the wall joins the coast at the southern limit of the map, pebbly schistose grits occur associated with thin rusty-weathering limestone bands. Garnets have been noticed in the siliceous rocks of this group, but are never conspicuous, and probably very rare.

Epidiorite outcrops are fairly well represented.

The structures of the district, so far as they can be observed, are more uniform than those found along the strike to the north of Car Mòr. Almost everywhere the bedding and main foliation dip at moderate or steep angles towards the north-west. In the more massive quartzites this dip is steady, but in the more schistose beds undulatory, and the main foliation is crossed by a strong secondary foliation dipping steeply to the south-east. E. B. B.

THE STRONCHULLIN PHYLLITES.

Between Gleann dà Leirg and Loch Stornoway, in Sheet 28, a narrow band following a south-south-westerly direction, that has been coloured as phyllite on the map, represents the schists now to be described.* No continuation of the band is shown in Sheet 29, as at the time when the ground was originally surveyed (1886 and 1887) it was not intended that minor outcrops should be differentiated. If the horizon of the Stronchullin Phyllites were coincident with that of the graphite schists, which in northern Cowal are interposed between the Garnetiferous Mica Schist and Ardrishaig Groups, its position would be of great stratigraphical value; but if, as the writer supposes, it merely represents a portion of the Ardrishaig Group, the band is only of subordinate importance. A brief description of its lithological characters will now be submitted.

District North of Loch Caoi-rain.—On the coast of Loch Fyne the band is not seen, but may be concealed beneath the beach deposits north of Creagan Beag. Between the coast and the western margin of the map (29) the belt is represented by quartzose schists, quartzose mica schists and silvery grey phyllites, but the wooded nature of the tract and insufficiency of rock exposure precludes a

* The outcrop of the group is in a region of intermediate metamorphism, where the pelitic beds may be termed either mica schist or phyllite.

determination of their relative proportions. On the eastern margin of Sheet 28 the band is dissected by the Stronchullin Burn, and there consists of grey silvery mica schists, darker leaden-coloured mica schists and subordinate bands of quartzite. A little further to the east, in the tributary of this river at the entrance to Gleann dà Leirg, silvery mica schists are exposed, some of which are calcareous. Proceeding a third of a mile up this stream in a southerly direction, dark coloured sericitic phyllites intermixed with thin quartzites are seen. A little further south calcareous mica schist occurs, of brownish to greyish hues, still intermixed with fine-textured quartzite bands. Three-quarters of a mile up the glen the burn section exhibits silvery phyllites, ranging in colour from grey to greyish blue and dark blue, with some quartzite bands, the phyllites or mica schists being in parts highly calcareous. Hitherto, the section that has been followed up the stream is a fairly typical representative of the Ardrishaig Series, in areas of a corresponding degree of metamorphism, although the green hues that are so commonly exhibited in the central belt of that division are here scarcely represented. But after leaving the main stream and ascending to the foot of a waterfall on the western slopes of Gleann dà Leirg, a dark shivery bluish black phyllite is found, portions of which are graphitic; parts of the dark phyllite are highly micaceous with silvery lustre, and a few bands of quartzite occur. This dark graphitic band has been drawn by Mr. Bailey, who was instructed to trace the boundaries of the Stronchullin Phyllites, with a breadth ranging from 30 to 50 yds., and although its outcrop may probably be exaggerated by folding, and thin graphitic bands are occasionally represented in the Ardrishaig series further to the north, the presence of a band of this magnitude is exceptional. On the other hand, while some dark phyllite that would represent a transitional stage to this graphitic zone occurs both in the section of the Stronchullin band previously described and in its southerly prolongation to be referred to later; still in no other part of the belt have we encountered phyllite that is comparable with this outcrop exposed at the waterfall, so that its occurrence within the Stronchullin Phyllite Group is local, and, we consider, altogether insufficient to play a dominant rôle in its lithology. In Gleann dà Leirg this band occupies a width of a third of a mile, but is by no means solely composed of phyllite, as quartz schists are extensively developed in the crags which mark the western slopes.

The head of the main stream draining into Gleann dà Leirg runs in the hollow east of Stuchd Bhreac, where phyllites are exposed in its channel. They are here represented by bluish calcareous silvery bands, together with some of darker hue which may form a connecting link with the black phyllite band already alluded to. At the extreme head of the stream and in the small eastern tributary, bands of quartzite are associated with blue silvery phyllite. Between this locality and the head waters of the Artilligan Burn—a distance of over a mile—the zone cannot be satisfactorily traced, and, after occupying a breadth of about a sixth of a mile along the upper course of the Gleann dà Leirg hollow, it has thenceforward been drawn as a narrow band, about 50 yds. in width, along the course of which some grey phyllite has occasionally been noted, while a

small parallel outcrop, about half a mile in length, has been mapped slightly to the westward. The main band is next seen in the Artilligan Burn, with a breadth of about 150 yds., and consists of calcareous mica schist, of the Ardrishaig type, pale in colour with a slight tendency to greenish hues, and although parts are darker than others we have observed nothing of the nature of the graphitic schist. Between the Artilligan Burn and Lochan Sgreagach the band is mainly represented by grey mica schist and quartz schist, while intercalated seams of darker schists have been detected as far as the stream north-east of Meall Beag, where Mr. Bailey has noted dark leaden schist with calcite folia. Beyond this point, however, to the extreme south-west of the belt, as will be seen in Mr. Bailey's description of that area, these darker zones no longer appear.

It is a matter of conjecture whether the Stronchullin Phyllites are an independent stratigraphical horizon separating two distinct quartzites, or whether they are merely an infold of one of the phyllite bands outcropping further to the north. The pelitic members of the quartzite group are increasing in their proportion in a north-westerly direction, so that the eastern margin of the main Ardrishaig Phyllite band is somewhat hypothetical. The Stronchullin band itself is in some places exceedingly ill-defined, especially in the area between Sheet 28 and the west side of Loch Fyne. J. B. H.

District South of Loch Caoi-rain.—The southern extension of the Stronchullin belt is occupied by more siliceous rocks than those already described. No black phyllite has been met with at all, and sections of grey phyllite unmixed with quartzite are always extremely limited. The group consists of a closely-banded series of mica schist and quartzite, the former predominating. It is naturally impossible to draw a strict stratigraphical boundary for such a group, and the interdigitation of the margin shown on the map is no doubt due at least as much to original interstratification as to subsequent interfolding. The group can nevertheless be followed with confidence to a point half-way between Loch a' Bhaillidh and Carse House. South of this, however, it altogether loses its individuality. E. B. B.

ERINS QUARTZITE, NORTH-WEST OF STRONCHULLIN PHYLLITE BAND.

Inverneil District.—This area is bounded on the south-east by the Stronchullin Phyllite band, while its north-western margin extends from Brenfield Point (Sheet 29) to a mile south of Loch Errol (Sheet 28). The district is traversed by an important fault—the Inverneil fault—which displaces the outcrops on the north-east for about half a mile to the south-east.

Before proceeding further, attention is again called to the fact that, whereas the eastern area bordering Loch Fyne was mapped long ago, the western district flanking the Sound of Jura has more recently been surveyed under conditions which admitted of more detailed mapping. As a consequence, instead of the twofold division of the Ardrishaig group in the Loch Fyne region, represented by a siliceous belt on the south and a pelitic belt in the north, the

western tract has been further differentiated into minor lithological subdivisions. This apparent discordance, resulting from the more detailed mapping in the west, is confined to Sheet 28, but another discordance affects the adjoining margins of Sheets 28 and 29. In the latter Sheet the northern boundary of the siliceous group was fixed approximately at the mouth of the Inverneil Burn, but the completion of the survey has resulted in the boundary being drawn further to the north-west in Sheet 28. The prolongation of the new boundary to the shores of Loch Fyne would come a little to the north of Brenfield Point. As a matter of fact, there is no sharp distinction between these major groups coloured respectively as phyllite and quartzite: the former contains a varying admixture of quartzite, while the latter, especially towards the north-west, incorporates a similar varying proportion of phyllite; there is, therefore, room for considerable latitude in the choice of a boundary between them. As the greater part of the Knapdale tract lies in the western region that has been recently surveyed, the boundary that has been adopted in that area has been continued through this eastern district. Even if it does not express the most satisfactory position within this limited tract, it is probably more applicable to the region as a whole.

The modification of the boundary on the coast of Loch Fyne, bringing the margin of the Quartzite group to the north of Brenfield Point, within the belt originally coloured as phyllite, necessitates a corresponding modification across Loch Gilp. For a distance of three-quarters of a mile to the north-west of the boundary drawn in that area, the amount of quartzite is such that, following the scheme of differentiation now adopted, it would be relegated to the siliceous group.

The coast section on the western shores of Loch Fyne has already been described as far to the north as Creagan Beag. Between the gap in the exposures representing the Stronchullin band and Brenfield Point, schists of sedimentary origin are represented by members of the group now under consideration, and a brief description of their relations will be given. For about a quarter of a mile south of Bagh an Tailleir, the rock exposures consist of quartzose bands containing calcareous seams, fissile quartzose mica schists, and pale silvery phyllites, generally pinkish but with slight indications of the green hues that characterise a large portion of the Ardrishaig Phyllites further to the north. In a northerly direction the rocks exhibit a progressive decrease of metamorphism, and the secondary biotites do not appear to be prominent. The strata are folded, and the axial planes of fold dip north-west, from 25° to higher angles. At the north end of the section there is a fault running north-west, evidently related to the dislocation along the Inverneil Burn, and carrying vein breccia from 4 to 6 ft. in width. From the north of Bagh an Tailleir to the mouth of the Inverneil Burn the strike has been considerably deflected by the afore-mentioned fault, and the strata incline E. 10° S. at angles ranging between 40° and 60°. In this belt the promontory opposite Inverneil Island is occupied by a band of epidiorite, on the south side of which are compact pinkish quartzose beds with seams of pink and green phyllite. To the north of that intrusion are

quartzites, quartz schists, quartzose mica schists and silvery phyllites, parts of which are calcareous, while the colours vary from brown to pink, and the lithological types are similar to those further south. Just south of the mouth of the burn there is a band, 6 to 8 ft. in width, of crystalline and micaceous white limestone with a brown weathered surface. To the north of the river the strike is again normal, and on the south side of an epidiorite are siliceous and pelitic rocks with thin seams of limestone from 6 to 9 in. thick. The sediments show contact alteration by the igneous mass and are much discoloured, and exhibit green, red and yellow hues. In Brenfield Bay the strata consist of quartzite, calcareous quartz schist, with colours ranging from grey to pinkish and brown, and subordinate silvery phyllite, while the inclination of the limbs of the folds averages about 30° to the north. At Brenfield Point greyish green calcareous quartzose and micaceous schists, with rusty brown limestones, are associated with epidiorite bands. There is a greater proportion of phyllite in this northern part of the section, but the lithological types show little difference from those to the south of Stronchullin. The phyllite principally displays pale and brown colours, some is slightly greenish, and parts resemble some of the dark portions of the Stronchullin Phyllite band. The section further north becomes more pelitic, and will be described later with the phyllite group.

Inland exposures present few distinguishing features from those that characterise the coast sections, and are represented by a similar assemblage of siliceous schists in which pelitic bands are subordinate, although transitional types of mica schist, formed by the metamorphism of fine sandy shales, are more common. Siliceous members displaying gritty structures have been noted a third of a mile south-east of Loch Fuar-Bheinne, while a belt running slightly south-east of these outcrops at the one extremity, and north-west of Cnoc Glas at the other, appears to be rich in pelitic material and may represent a folded repetition of the Stronchullin Phyllite band. Further to the north-west, pelitic schist has been noted amongst the siliceous schist at various places, namely, to the north-east of Lochan Anma and also to the north-east of Loch Errol, while in the hollow occupied by the main road in the last-named locality, the micaceous material exhibits dark hues recalling part of the Stronchullin band. Besides the small calcareous seams so commonly interspersed throughout the siliceous series, there is in the vicinity of Loch Fuar-Bheinne a marked development of limestone. On the north-east shore of that loch there are two limestone bands, one of which is from 15 to 20 ft. in thickness, intercalated between fine-textured quartz schist and dipping at 25° to the north-west. The limestone is of a greyish colour and is impure, being not only micaceous but likewise sandy. On the south-west side of that loch, it forms a lenticle nearly half a mile in length and with a maximum breadth of about 250 yds. It is highly contorted and forms the cap of the hill and adjacent slope, resting on quartz schist; the size of the outcrop is evidently due to its nearly flat position, and the thickness probably does not exceed that of the band last noted, as inliers of the underlying schist are observed within the heart of the exposure. To the south-west it is represented by smaller and isolated outcrops on the borders of the

peat moss at the foot of An Creachan. Thin seams of limestone and calcareous schist are likewise exposed in the bed of the Inverneil Burn. J. B. H.

A thick, banded, cream and grey limestone has also been followed for a considerable distance above the high road and to the east of Loch Errol. In some of the exposures there are two or more parallel outcrops, which do not appear to be in all cases due to repetition of a single bed by folding. This limestone is clearly associated with a mixed series of quartzite and subordinate grey phyllite. It lies not far within the boundary chosen for the quartzite group. The best exposure is a little above the road a mile south-west of Loch Errol. E. B. B.

Epidiorites are represented in the north-east corner of the district by some large bands at Inverneil and some smaller seams in the vicinity of Brenfield. Between the Inverneil Burn and Cnoc na h-Iolaire, to the south, these rocks are not represented, but, as will be seen presently, they recur along the same line of strike to the south. J. B. H.

Baranlongart and Loch Stornoway District.—The Erins Quartzites are well seen on either side of the Baranlongart Burn, and form a thin-bedded series with occasional partings of phyllite. Outcrops of limestone also occur, and, as these all seem to be closely associated with epidiorite sills, perhaps not more than one bed is represented.

The limestone is well seen at An Torr (Baranlongart) and also at several points in the Baranlongart Burn, near the old Fort. The An Torr exposure is on the line of a series of outcrops, already described, passing to the west of Loch Errol and near the passage from the quartzites into the phyllites to the west. The position of the bed is thus close to the phyllites, and, as it seems to crop up again for some distance to the east, it suggests that the area is affected by very shallow folding. Another exposure of limestone occurs about 200 yds. west of Achadh Cul a' Bharr, and may represent the same bed, although it lies well outside the boundary drawn for the quartzite series.

The limestone is a cream-coloured sandy rock with occasional flakes of biotite, and often contains hard compact ribs of calc-silicates and felspar. Among the calc-silicates are zoisite, vesuvianite and augite (12529, 12530, 12536–8).

South of the Baranlongart Burn the separation of the Erins Quartzite belt from that of the phyllitic portion of the Ardrishaig Group can, as usual, only be effected in an approximate manner. An important band of quartzite crops out about a mile from the coast, just to the east of some conspicuous epidiorite ridges. The quartzite is more or less micaceous. Beyond this to the east are phyllites, a bed of limestone associated with an epidiorite sill, and then quartzite again. The position of the limestone with reference to the epidiorite varies considerably, the bed being sometimes found on the one side, sometimes on the other, while for a considerable distance its outcrop is central. Where it occurs to the south-east of the epidiorite, it is separated from the succeeding quartzite by a narrow band of phyllite.

The limestone is evidently the continuation of the An Torr and Loch Errol outcrops, already described, to the north. It is a white crystalline marble occurring in beds usually several inches thick and sometimes separated by calcareous phyllites. It is perhaps 20 ft. thick south of Lochan na Craige, where the remains of limekilns show that it has been calcined in the past. A thin bed of pebbly grit can be seen in one place between the limestone and the phyllite to the south-east of it.

East of the limestone the quartzite comes on in force, and, with massive epidiorite sills, forms the greater part of the country as far as the upper reaches of the Abhainn Mhor. It is generally a fine-grained white quartzite, but sometimes contains pebbles of felspar and blue quartz. Locally it is felspathic or micaceous, or exhibits a type of weathering suggestive of a slightly calcareous matrix. Thin beds of phyllite and limestone occur, which are probably for the most part infolds of beds cropping to the west. The limestone occurs on the margin of a large epidiorite, and is in contact with the phyllites, as in the main outcrop. It lies about half a mile east of the latter. The only trace of it left in some places is a little calc-silicate-hornfels on the margin of the epidiorite. A peculiarly beautiful type of this hornfels, penetrated by hornblende needles, occurs a third of a mile south of the southern end of Loch a' Chaoruinn.

The massive epidiorite intrusions which occur on this horizon may to a large extent be repetitions of one bed. Thus the cappings of An Gobhlach and Doire Chreagach are obviously portions of the same epidiorite folded over from an outcrop lying to the west.

East of the region of epidiorites the quartzite becomes rapidly very impure and passes into a quartz schist, with abundant development of mica throughout the mass, and here and there bands of more or less quartzose phyllite. In one or two places it is seen to contain felspar pebbles, and in Coire Mhaim there are a few thin beds of limestone. W. B. W., H. B. M.

The increased tendency to pelitic intercalation is interrupted by a more quartzose band before reaching the Stronchullin Phyllite belt. This quartzose band between Cnoc na h-Iolaire and Cnoc a' Bharaille contains a marked development of epidiorite outcrops, and their irregularity of outline admirably expresses the folding of the district, especially in the vicinity of Meall Beag. Along this south-eastern margin of the belt, between Meall Beag and Meall Buidhe, dips in contrary directions have frequently been observed.

J. B. H.

To the north and south of Loch nan Torran the Erins Quartzite is composed of alternating bands of soft brown quartzite and quartz schist all folded together. This quartzite is sometimes gritty, but never pebbly. Here and there appear more massive bands of quartzite which contain a little brown mica. The quartz schist is frequently associated with thin calcareous bands which, to the south of Lochan Eun and the slopes of Cnoc Reamhar, both near the western margin of the group, develop into beds of fawn and drab limestones about 4 ft. thick.

A very typical section of the Erins Quartzite is exposed in the Allt Airidh Sheileach. The boundary between the quartzites and

the phyllites to the west is an intricate one on account of the isoclinal system of folding affecting the strata. No doubt, also, there is considerable interstratification of the two different rock types. West of the line shown on the map there are numerous bands of fine-grained light brown quartzite interfolded with the phyllites. These quartzite bands are identical in character with those already described outcropping to the east, and represent the upper portion of these beds brought to the surface along the crests of isoclinal anticlines or similar beds actually interstratified with the phyllites. J. S. G. W.

The Allt Airidh Sheileach has already been mentioned as affording a good section of the portion of the Erins Quartzite near the outcrop of the main Ardrishaig Phyllites.

The upper portion of the burn is crossed by an important band of quartzo-phyllitic beds in which grey mica schists and quartzite ribs are intimately interbanded, just as they are in the southern part of the outcrop of the Stronchullin Phyllites. There is no reason to imagine that the band occupies the centre of a fold merely because it has not been possible to follow it far to the north, since it appears in the field to be becoming more indefinite in this direction owing to increased intercalation of quartzose beds. To the south it is much more easily recognised, although its boundaries are somewhat arbitrary. Much the best exposure is furnished by the fine cliffs of the 25-foot beach west of Loch Stornoway, where the phyllitic material seems to have reached its maximum development. In this increase in pelitic character towards the south, the outcrop differs from the Stronchullin band, which becomes unrecognisable before reaching Loch Stornoway.

The rocks separating these two phyllitic groups largely consist of quartz schists with occasional massive beds of quartzite and subordinate mica schist. Pebbles are rare, as usual, but have been noticed in gritty bands on Cruach a' Bhaillidh and elsewhere. The quartzites have probably a very slight proportion of calcareous cement, for such is not uncommon in the Erins Group. A thin seam of very impure limestone has been noted in the heart of the quartzites west of Loch a' Bhaillidh.

A similar series of white quartzites, associated with more micaceous seams, separates the central phyllitic belt from the main phyllitic outcrop to the west. Here, too, pebbles are very exceptional. The marginal limestone horizon is represented by 8 ft. of grey limestone, near Keppoch Point, in the phyllites, and by a buff limestone in the quartzite series. The latter, although a well-marked band in the raised beach cliff, where it is accompanied by sandy phyllites with minor limestone streaks, is scarcely represented at all in the actual coast section. Another limestone band is exposed on the shore towards the eastern limit of the quartzose group.

The epidiorites of this southern region are very interesting in their comparative disregard of the distribution of the sedimentary subdivisions. It appears likely that they are intrusions with a more than usually transgressive habit. At the same time, of course, many individual peculiarities in the boundaries of the outcrops have been determined by folding. The structure of the district continues that of the country lying to the south-east. A

prevalent north-westerly dip of bedding and foliation obtains, at angles which are either moderate or high. The contortion of the first foliation and the production of a strain-slip cleavage, dipping to the south-east, gradually disappear in a north-westerly direction across the strike. E. B. B.

ERINS QUARTZITE, NORTH-EAST OF LOCH GILP.

The area here described forms the coastal tract on Sheet 29 between Loch Fyne and a line connecting Calard Rudha with the northern edge of the map about half a mile west of West Kames.*

The south-easterly limits of the group are occupied by the sea, but the writer believes that the tract lying to the south-east of the line just referred to is almost entirely represented by that part of the quartzite group which occupies the coastal tract of western Loch Fyne between Stronchullin and Erins. If the Stronchullin Phyllite band were prolonged across Loch Gilp, in the direction that prevails for the last 2 miles of its course, it would pass somewhat to the north-west of the line just mentioned; but before reaching the shore it has to cross faults which displace its outcrop in the opposite direction, towards the south-east. Each area contains at least 5 miles of coast section, the comparison of which reveals such a close lithological resemblance that the writer has found no difficulty in correlating the rocks of the two regions.

A brief description of the coast section will now be presented. The promontory extending from Castleton House† to the point at Calard Rudha is made up of compact bedded quartz schist and quartzite, calcareous in part and with zones of gritty schist, amongst which is some quartzose mica schist, but phyllite is scarcely represented except as thin partings between the more massive bands. The beds vary in colour from grey to greyish green, and the limbs of the folds incline steadily to the north-west, mainly at a high angle; at the west end of the section it is 45°. In the promontory west of Glac Mhor, closely adjoining, a dip of 65° has been noted; the strata there consist of quartzite and quartz schist, some of which clearly show a fine-grained clastic structure, while occasional lenticles, that swell to a foot or so in width, are of coarser texture. The quartzose bands are divided by partings of phyllite of the Ardrishaig type. The coast east of Silvercraigs is made up of alternations of quartz schist and quartzite, partly calcareous, with partings of thinner mica schist. The strata are dipping steeply to the north-west, in one place at 60°. To the south of Achnaba, where dips of corresponding direction and ranging from 50° to 65° have been observed, banded quartzite, quartzite schist and quartz schist, with calcareous lenticles and often pinkish in colour, appear to correspond to the group of siliceous schists of the coast to the north of Erins. Similar strata intermixed with quartzose mica schist occupy the shores from this locality to the north of Achnaba, where the rocks are concealed beneath boulder clay and alluvium. The coast between Port Ann and West Otter

* The line engraved in the map lies further south-east. See the description of the Inverneil district, p. 40.

† Now known as Shirvan.

Ferry presents a similar assemblage of compact bands of quartzite, quartz schist, gritty quartz schist and quartzose mica schist, pinkish to grey in colour, and the section seems identical with that between Srondoire and Erins. The bands are sometimes contorted, but there is a constant north-westerly inclination of the folded limbs, often at a high angle, 50° being noted near West Otter Ferry. The remainder of the section to the northern edge of the map is but slightly oblique to the strike, and consists of massive quartz schists and quartzite schists, some of which display gritty structure and correspond in type with those north of Erins.

The inland tract presents features analogous to those on the coast, and there is a similar dearth of phyllite. A few thin seams of limestone associated with calcareous schist are seen in the burn below Alltoigh. No bands of the Green Bed type have been detected, and we are apparently beyond the extreme limits of that phase of deposit. In Knapdale they are only seen towards the south-eastern margin of this group, and the corresponding horizon in this district would lie beneath Loch Fyne. In the upper reaches of that fiord Green Beds have been observed in the lower members of the Ardrishaig division, north-west of which they no longer appear, so that in this respect the evidence in Cowal is in accord with that of Knapdale and the district being described.

The epidiorite intrusions usually take the form of lenticles, that may swell to a width of 250 yds. The more important of these occur at the following localities: the island east of Glac Bheag, the promontory of Silvercraigs and its islet prolongation to Liath Eilean, north of Alltoigh, and the vicinity of Carrick.

J. B. H.

CHAPTER VI.

THE METAMORPHIC ROCKS OF THE MAINLAND.—(*Continued*)

VII.—Phyllites of the Ardrishaig Series, North-West of the Erins Quartzite.

This group of phyllites does not include the whole of the Ardrishaig Series, as commonly defined in the district of Upper Loch Fyne, as the Erins Quartzite is, in part at least, a member of the Ardrishaig Group. The phyllites are admirably exposed at many points along their outcrop, especially on the shores of Loch Gilp and the western coast of Knapdale. They consist essentially of a group of grey-green phyllites, with intercalations of fine-grained white quartzite, and are usually slightly calcareous. Special features will be discussed in the sequel, where subdivisions are described, of at least local importance, based either upon variations of colour or the relative abundance of siliceous bands. Pebbly and even finely conglomeratic beds although rare are also referred to, their occurrence within the Ardrishaig Group being a novel and interesting feature.

The phyllite tract occupies the greater part of the shores of Loch Gilp. Its south-eastern boundary lies about a mile within the mouth of that loch, while its opposite margin passes about a mile north-west of Lochgilphead, almost exactly through the corner of Sheets 28 and 29. The band pursues an even course as far south-west as the Inverneil fault, where it is shifted for about half a mile to the north-west. Thereafter it maintains its south-south-westerly direction without any important deflections, its south-easterly boundary passing out to sea through Kilberry, and its north-western limit being exposed in Port Ban, to the north of the Point of Knap.

Loch Gilp District.—This area embraces that part of the band coloured as phyllite in which Ardrishaig occupies a central position, from the northern edge of the maps (28 and 29) to the hollow partly occupied by the Lussa and Inverneil Burn: it is bounded on the south-east by the quartzites of the Erins division described in the previous section, and on the north-west by the Loch Awe Group, the margin of which is represented by a line between the north-eastern corner of Sheet 28 and the valley of the Lussa, about three-quarters of a mile east of Bacoch's Seat.

This band, although mainly phyllitic, includes quartzites and quartz schists as well as lithological types connecting those rocks and phyllites. While doubtless the siliceous zones to the south-east are represented by infolds within this band, the interstratification of quartzite and phyllite is nevertheless clear, and in some tracts the

former is so extensively developed that with a more detailed scale of mapping certain siliceous subdivisions could have been shown within the phyllite area. The proportions of siliceous and pelitic rock vary considerably, but it is rare to find the former altogether absent.

The phyllites exhibit much variation but are very commonly calcareous, the lime either forming laminæ between the pelitic material, or occurring in a state of diffusion throughout the rock. In some cases the calcareous partings are larger and expand to a foot in thickness or even more. Beds of this size are uncommon, although limestone interlaminations of a few inches in width are frequent, not only amongst the pelitic but likewise in the siliceous members. The limestone bands effervesce freely with dilute hydrochloric acid, are of pale colour, and weather into rusty brown tints. The siliceous members of the group, consisting of quartzites, quartz schists and quartzose mica schists, are identical in character with those occupying the adjacent band to the south-east, and therefore call for no further description. Not only do the phyllites exhibit variations depending on the presence or absence of calcareous matter, but also distinctions in colour, resulting from the diffusion of chlorite and carbonaceous matter. Green colours of various shades prevail throughout a large portion of the bands. In other parts of the belt the tints are grey-blue, dark blue and leaden black, varying with the proportions of carbonaceous matter, the darker portions being, in rare instances, graphitic and yielding the characteristic streak of that mineral. Again, other parts of the band are neither chloritic nor carbonaceous, and are of pale greyish brown, pink or reddish hues, due to the diffusion of iron oxide, which stains the rock, especially along the cleavage, bedding and joints.

In describing the field relations of the rocks in this group, we shall commence with the coast section of the Knapdale tract. That part coloured on Sheet 29 as phyllite, between Whitehouse Bay and Brenfield Point, has already been described with the Erins Quartzite, as the proportion of siliceous strata incorporated link it with the latter. To the north of Brenfield Point are pinkish quartzites, mica schists and phyllites, partly calcareous, while some of them exhibit greyish green hues. About a quarter of a mile north of the same locality these are succeeded by calcareous greyish blue lustrous phyllite and dark leaden phyllites, similar to the type exhibited in the Stronchullin band. With these occur some thin black seams that are just as graphitic as that described within the latter band, on the western slopes of Gleann dà Leirg. The calcareous intercalations are represented by thin seams of limestone, which range up to 6 in. in thickness. These are succeeded by quartzites and mica schists, much contorted and of yellowish and reddish brown hues passing into greyish green. Nearly half a mile north of Brenfield Point some typical green phyllites, in which dark green mica is the principal ingredient, occur near bands of epidiorite. A little south of Woodhouse and, again, just north of that locality, the strata consist of greenish and greyish silvery calcareous phyllites, in parts highly lustrous, with subordinate intercalations of thin quartzites, that become stronger towards the south, and narrow rusty brown limestones, ranging from an inch in thickness to the thinnest films. The metamorphism is not quite so advanced as in the vicinity of Stronchullin, and no black mica has

been detected, but there are blotches due to the segregation of chlorite or green biotite. At Creag a' Ghuail, massive epidiorite has indurated the phyllitic margins, with the production of porcellanite. For the next half a mile further north there is a raised beach deposit, from beneath which crumpled green phyllites with intercalations of quartzite and quartz schist occasionally emerge. On the south side of the breakwater at Ardrishaig, a sill of hornblende schist is seen in which some quartz schist and phyllite are incorporated. Between the harbour and Ardrishaig Hotel the exposures consist of green mica schist, while on the shore opposite the Hotel are two outcrops of hornblende schist and a large basalt dyke. Between this locality and the mouth of the burn at Glendarroch are green mica schists and bluish phyllites, with intercalated silky quartzose flagstones, which contain sufficient mica to split readily along the foliation planes. Similar silky beds are again seen just north of the mouth of the burn, and on the shore almost due east of Brackly they are associated with bluish and greenish phyllite. Thence, northwards, to Lochgilphead the solid rocks are not exposed on the shore, but on the west side of the Canal they consist of greyish blue phyllites with subordinate bands of quartzite or quartz schist. Near Oakfield Bridge (south of Auchindarroch) two narrow seams of limestone abut on the roadside bordering the Canal. From this point to the northern edge of the map the strata are represented almost entirely by bluish slate, often calcareous, and with subordinate seams of quartzite, while epidiorite forms a considerable spread in the vicinity of Auchindarroch.

Although the section from Brenfield Point to the northern edge of the map shows much crumpling and isoclinal folding, the inclination of the folded strata is almost invariably towards the north-west. To the south of Ardrishaig the average inclination ranges from 20° to 30°, while north of that locality it varies from 20° to 45°.

The inland tract adjoining the sections described shows almost a repetition of the strata seen along the coast. The belt lying north-west of a line connecting Glendarroch with Cruach na Brenfield is mainly occupied by blue phyllite, which is especially well seen in the burns near Auchindarroch, Brackly, and to the west of Glendarroch. The adjacent beds lying between that belt and a line running to the south-west from the coast about half a mile north of Brenfield Point are mainly composed of green phyllites, an excellent section of which is afforded by the burn flowing into Loch Fyne near Attichuan Cottage.* A third and narrower phyllitic zone, extending to the south-east margin of the group, consists of pale grey and pinkish types, with subordinate blue and green bands.

Although, as previously observed, siliceous bands are distributed almost throughout the group, yet in certain zones they play a predominating rôle; one of these extends from the coast north of Ardrishaig Pier to the hollow between Cruach na Brenfield and Cnoc nam Muc, while another lies between Beinn Bheag and the hillside above Brackly Farm. Grits are mainly confined to a north-

* A third of a mile south of the entrance to the Canal.

western marginal tract, about a mile wide, but they have been occasionally observed farther to the south-east; fine-textured grit bands occur, for instance, behind Ardrishaig, and extend for some distance to the south-west on apparently the same horizon.

Thin seams of grey limestone cross the burn a quarter of a mile west of Glendarroch, and rotten brown sandy bands, out of which the calcareous matrix has been dissolved, occur in the stream south of the Canal Bridge west of Lochgilphead, apparently on the horizon of the limestone already noted at the latter locality.

This tract is characterised by an enormous development of epidiorite intrusions that form large parallel bands running north-east and south-west; these sills admirably reflect the isoclinal structure of the district. As a glance at the map will show, although presenting a general parallel arrangement, many of the smaller bands represent branches which merge into a single trunk, and reduplication by folding is a common feature. Some of these sills can be followed for long distances; one, for instance, the central portion of which forms the peak of Cruach nam Bonnach, being traced to the south-west for nearly 3 miles, where its continuity is severed at last by the Inverneil fault. The mass to the west of Ardrishaig, the highest portion of which forms the summit of Cnoc Odhar, has a maximum breadth of nearly half a mile, and, although it has only been traced for a length of about $1\frac{1}{4}$ mile, it probably continues, beneath the surface deposits of peat and drift, to the outcrops to the north-east and south-west respectively.

The tract on the eastern side of Loch Gilp (Sheet 29), lying within the parish of Kilmichael Glassary, exhibits analogous types and structures to those of the Knapdale area, and it will only be necessary therefore to give a brief account of it. The Carrick area coloured as quartzite schist on the map has already been described with the Erins Quartzite Group, and it has been pointed out that the marginal portion of the area coloured as phyllite on the map, running north-west through Ballimore and Achnaleppin, corresponds with the north-western part of the belt mapped as quartzite in Sheet 28. Not only are siliceous rocks strongly developed in this belt, but the associated phyllite is mainly of the grey and pinkish types that characterise the quartzite group. The more pelitic tract lying to the north-west is moreover divisible into the same bands, marked by differences of hue, as in the corresponding horizons in Knapdale.

The coast-line from Creaglan to the edge of the marine terraces at Kilmory affords an excellent section of the strata. At Creaglan there is a succession of compact quartz schists and quartzose mica schists, calcareous, and displaying pinkish and reddish hues. Just beyond the mouth of the Lingerton Burn, immediately north of Creaglan, silvery mica schists, mainly of a pale grey colour, are associated with quartzite bands and some pale grey calcareous quartzose schist, while some narrow seams of brown impure limestone form bands about a foot thick. These beds are intermixed with seams of epidiorite, and have been partially baked by them. Quartz schists and quartzose mica schists, calcareous, with subordinate pelitic bands and small bands of epidiorite, occupy the section as far as the burn nearly half a mile north-west of Creaglan. From thence

to the point opposite Duncuan Island calcareous phyllite predominates, although some bands are more quartzose. Similar strata extend northwards along the coast for another 600 yds. Although the latter part of the section lies within the zone of green phyllites, already mentioned on the west side of the loch, the hues on this coast are faint. About 600 yds. north of the point opposite Duncuan Island there are some bluish grey phyllites and thin quartzites, the latter being divided by partings of pale grey phyllite. From thence to a little north of Kilmory Pier, quartzite, quartz schist and quartzose mica schist are well developed, while still farther north phyllites, sometimes greyish blue and purplish, form the predominating type.

Turning now to the inland tract, the characteristic green phyllites are developed in a belt, nearly a mile in width, extending eastward from Kilmory. To the north-west of that belt the bluish phyllites are strongly represented, while on its south-east side the pale grey and pinkish types predominate. Quartzites and quartz schists are distributed throughout the entire area, but are nevertheless most strongly developed along certain lines of outcrop, one of which extends from Kilmory to the Blarbuy Burn, while a parallel band passes slightly to the east of Dunmore. Thin seams of limestone, usually very impure and sandy, are seen near Blarbuy, but are generally too small to be mapped.

The average dip of the folded strata from Ballimore to Lochgilphead ranges from 45° to 60° towards the north-west, whereas in the corresponding beds on the opposite shore of Loch Fyne the prevailing range is from 20° to 45°. This increase of dip is accompanied by a contraction of the belt, very much as would be expected amongst unfolded strata. The width of the entire band coloured as phyllite in Sheet 29 is about 3½ miles in the Knapdale tract, and from 2½ to 3 miles in this region east of Loch Gilp. The outcrops of the epidiorite sills, also, are narrower than in the corresponding horizon to the west of Ardrishaig. Such variation of the breadth of outcrop with a corresponding change of dip is found, also, in the Stonefield Group, which on the western side of Loch Fyne, where it is vertical or steeply inclined, is considerably narrower than the corresponding group in Cowal, extending from Kilfinan Bay to the northern edge of the map 29, where lower dips predominate.

J. B. H.

Central District.—The central district of the phyllite belt extends from the Inverneil fault to Achahoish on the east side of Loch Caolisport and Eilean na Bruachain on the west. A rough threefold division of the outcrop can be recognised, the following groups being met with in succession in a traverse from south-east to north-west:—

(*a*) Phyllites with bands of quartzite.
(*b*) Homogeneous grey or green phyllites, free from intercalations of quartzite.
(*c*) Phyllites with quartzite bands and at least one bed of sandy limestone with pebbles.

It is likely that these subdivisions have a stratigraphical basis, and are not merely dependent upon varying degrees of repetition, by folding, of the constituent rock types. The south-easterly group (*a*),

which starts from the somewhat arbitrary margin chosen for the Erins Quartzite, includes fully half of the phyllite outcrop. The homogeneous belt (*b*) is only from half a mile to a mile across; it has been followed through Cnoc Mhadadh, Creag Raonuill and Cnoc Dubh to the sea. The third group (*c*) is on the average somewhat wider than the last-named; the quartzite outcrops occurring within it increase in importance along the strike to the south-west. Its relations to the Loch Awe Group will be described in the next chapter. Epidiorite intrusions are considerably less abundant in the middle quartzite-free belt than in the other two. The district will now be considered in more detail, commencing with its northern portion. C. T. C., E. B. B.

The south-eastern group (*a*) is very greatly split up with epidiorite intrusions. Its quartzite bands, as usual of a fine-grained white type, are much inferior in importance to the phyllites with which they are associated. Their north-western limit is fixed approximately by the lower part of Easan Tom Luirg, at the foot of Meall Ruadh.

The homogeneous phyllites (*b*) are well exposed in cliffs at the southern extremity of Cnoc Mhadadh, and again in the fine stream section north of Creag Raonuill.

The quartzite bands in the group (*c*) to the north-west, are, in the northern part of the central district, seldom more than 2 or 3 ft. thick. A comparatively wide outcrop, east of Feur Loch, is probably due to repetition by gentle folding. A crag of quartzite, too small to indicate on the map, occupies the acute angle of the epidiorite outcrop midway between Feur Lochan and Creag Raonuill; the beds are mostly of the normal fine-grained type, but associated with them are three parallel outcrops of sandy limestone containing distinct pebbles. Whether or no these represent more than one bed is a matter of little importance, but there can be no doubt that they belong to the Ardrishaig Group, and are not outliers of the Loch Awe Series.

A considerable outcrop of grey-green phyllites occurs to the west of the boundary of the Loch Awe Group, and is well exposed in the Allt Buidhe. It seems probable that they represent an inlier of the Ardrishaig Group, especially as they are associated with fine-grained quartzite. As will be pointed out later on, the two margins of the exposure do not agree at all closely, and for this reason the western boundary of the phyllites is supposed to be a fault. E. B. B.

A third of a mile south-east of Cnoc Dubh, near the head of Loch Caolisport, two outcrops of compact fine-grained quartzite schist, one as much as 50 yds. broad, occur within the division (*a*), and mark its north-west limit. The quartzite of these outcrops cannot be distinguished from that occurring to the south-east, and may perhaps be merely a recurrence of the same, due to folding.

The next division (*b*), containing the greatest proportion of phyllite, is well seen near Creag Raonuill, and also on the bare slopes of Cnoc Dubh, west of Gleann Cinn-Locha. In the latter locality it is almost free from intermixture with quartzite or epidiorite for a

breadth of about half a mile across the foliation, but it is no doubt considerably folded. The common type of phyllite in this part is of a pale grey or greenish grey colour, very soft and somewhat calcareous. The foliation planes are lustrous with abundant small scales of white mica or of chlorite—often just sufficiently large to be individualised with a hand lens. Biotite has not been observed. Occasional thin stripes of ferriferous carbonate can be recognised microscopically, but most of the carbonate is intimately diffused throughout the mass. Small cubes of pyrites and octohedra of magnetite are not uncommon. Slide 11507, from a specimen collected nearly half a mile N.N.W. of Cnoc Dubh, contains a few very small prisms of tourmaline—possibly of clastic origin. Small veins of quartz, or of quartz mixed with chlorite and little patches of ferriferous carbonate, are tolerably abundant.

These phyllites are not infrequently mixed with thin seams, sometimes hardly an thick inch, of impure calcareous siliceous schist or impure buff limestone.

A third of a mile north-west of Cnoc Dubh, comes on, apparently over the more homogeneous phyllites, the division (*c*) composed partly of phyllite and partly of bands of compact fine-grained quartzite schist, of white or pale buff fracture, together with many sills of intrusive epidiorite. These quartzite schists exhibit repeated folding, and it seems probable that the bands which pass about a third of a mile north-west of Cnoc Dubh and those which come into Ellary Burn, about a mile above Ellary, are the same. Some parts of the quartzites are calcareous and show small clastic grains of quartz with little or no deformation, the calcareous matrix having apparently behaved as a readily movable or yielding cushion during the shearing movements.

Rather more than half a mile slightly south of east of the outlet of Loch na Fola a calcareous quartzite or sandy limestone, 3 or 4 ft. thick, contains clastic grains of quartz as large as peas. It occurs on the west margin of a fine-grained quartzite. Two hundred yards farther south, within the quartzite outcrop just mentioned and immediately north of the northernmost of the two convergent faults shown on the map, another sandy limestone of about the same thickness is exposed. It contains, in addition to round grains of blue quartz, small pieces and thin lenticles of limestone, weathering with a brown crust, which are much more free from quartz grains than the general matrix: many of the pieces have sharply defined margins, and appear to be pebbles.

The axial planes of the most pronounced folds in the area between Achahoish and Ellary strike N.N.E. The western limbs of the anticlines are often nearly horizontal, but the eastern are inclined steeply W.N.W., and are the most thinned. The axial planes and foliation planes, which are parallel to the axial planes, are also inclined steeply in this direction. A number of folds near Cruach nam Lochan and Maoile Fhuar pitch N.N.E. at various angles, sometimes as high as 42°.

Besides the folds with steep axial planes, others, of minor importance and later date, are not uncommon, the axial planes of which are almost horizontal or inclined west at a small angle. Examples of these are well seen on the coast a mile west, and again about

1⅓ mile W.S.W. of Achahoish. They are occasionally observed to affect the limbs of the folds with steep axial planes, and to move the upper parts a little west of the lower.

On the coast between Ellary and Achahoish the general direction of stretching is indicated by the elongation of small carbonate specks, and is nearly the same as the direction of dip of the foliation planes.

C. T. C.

South-Eastern District.—This district consists of the coastal strip from Achahoish to Kilberry. It lies wholly to the south-east of the quartzite-free belt of homogeneous phyllite (*b*) of the central district. Whether this demonstrates a stratigraphical distinction between the rocks outcropping on the two sides of Loch Caolisport is not, however, certain, for a thin bed of conglomerate is found on the shore near the mouth of the Baranlongart Burn resembling one which, as will be described later on, occurs in Eilean nam Muc and elsewhere to the west of the loch. This point will be returned to in the discussion of the south-western district. Epidiorite sills are comparatively sparsely developed.

In the vicinity of the Baranlongart Burn the phyllite group (*a*) is not sharply defined from the Erins Quartzite Group, but as we pass north-west, from beds which certainly belong to the latter group, the quartzite bands become fewer and smaller, while the phyllitic material increases and predominates. The phyllites vary considerably in composition: in some places they are green, highly micaceous rocks, while at others they are dull and impure. The planes of schistosity are often puckered into little folds which may give rise to a strain-slip cleavage. The phyllites themselves are never free from bands of quartzite for more than a few yards. The quartzites weather with an almost white colour, and form conspicuous features on the hillsides, but in fresh fractures have a brownish colour, perhaps due to the presence of ferrous carbonates. The microscope shows that the clastic structures have suffered very little deformation. A thin limestone, in the northern part of this district, 200 yds. west of Achadh Cul a' Bharr, has already been alluded to as possibly a folded repetition of the Loch Errol Limestone. G. W. G.

The wooded slopes extending from the shore, between Ballyaurgan and Ormsary, up to the first ridge of the hills consists of greenish grey phyllite containing only a few narrow belts of quartzite and epidiorite. The phyllite in most places contains thin, dark greenish quartzose bands, by means of which the bedding is rendered conspicuous. It commonly dips at high angles (60° to nearly vertical) to the west-north-west. The cleavage also dips at high angles in the same direction, but it is greatly obscured by a minute puckering and frilling, seen on fractured surfaces of the phyllite and caused by a strain-slip cleavage. The latter structure is the result of a set of minute closely spaced folds passing into faults, the planes of which are inclined at low angles (20° to nearly horizontal) to the west-north-west. Each lamina of rock has moved, generally towards the east-south-east, over the one below it. Immediately on each side of the little fault-planes, the mineral particles, especially the mica scales,

which were originally lying parallel to the cleavage, have been dragged round, so that they tend to lie parallel to the strain-slip cleavage. The puckering and frilling is thus due to the distortion of the planes of first or slaty cleavage. The schistosity of the phyllite, or the direction in which it tends to split most readily, is along the distorted planes of the slaty cleavage, whilst there is also a tendency to part along the strain-slip cleavage. The presence of the latter structure renders the phyllites useless as roofing slates.

Pyrites in small cubes is not uncommon in the phyllites, but on the shore section W.N.W. of Ballyaurgan the cubes reach the unusual length of $1\frac{1}{2}$ in.

The quartzite is nearly always micaceous, sometimes slightly calcareous, and rarely contains a few pebbles of quartz.

The epidiorite crops out in narrow belts or lenticles, and, owing to its greater hardness, form distinct ridges or scarps. For the most part it is strongly schistose, but the outcrops near Ormsary are of the massive variety.

East of the first ridge of the hills a thin epidiorite sill intruded into the phyllites is repeated by folding, in several outcrops, which form conspicuous ridges. It is succeeded almost immediately by a belt of more or less micaceous quartzite, which has already been taken as the starting-point for the description of the Erins Quartzite in this locality. W. B. W., H. B. M.

An excellent section of the phyllite group (*a*) is exposed along the shore from Sgeir Moire, near Kilberry, to Ormsary House. On this shore-line, along with the soft and easily denuded phyllite, there are several bands of epidiorite and hard brown quartzite, which compose the numerous headlands and points, while the phyllites have been carved into picturesque bays and "ports."

Occasionally the calcareous bands seen along this part of the coast develop into thin impure limestones. An 8-ft. bed, at Keppoch Point, has already been alluded to as an example of the tendency for limestone to occur in the marginal phyllite-quartzite zone.

The original bedding is well preserved, and has an average dip of 35°–45° to W.N.W. Although this coastal belt of Ardrishaig Phyllites attains an average width of $1\frac{1}{2}$ mile it is doubtful whether it represents any large thickness of strata, since quartzite outcrops appear at frequent intervals all through the area, and may be isoclinal repetitions of the Erins Group. J. S. G. W.

South-Western District.—The area here considered extends south-west from Eilean na Bruachain and the Ellary Burn to the Point of Knap; its western boundary is defined by the somewhat jagged edge of the Loch Awe Group, which reaches the sea at Port Ban. The district, thus defined, belongs to the phyllite group (*c*) which contains quartzite bands within its borders. These beds of quartzite are sometimes very abundant, as at A'Chrannag, for instance, where they almost predominate over the phyllites. A rather important little bed of conglomerate has also been found which recalls the pebbly, and even conglomeratic, tendency noticed already in a bed, or beds, occurring in this group (*c*) in the district to the north-east. J. S. G. W., G. W. G.

The conglomerate bed contains pebbles of limestone, vein quartz and pieces of blue quartz, set in a calcareous matrix with abundant sand grains. The limestone pebbles are generally of different shades of grey, and weather with cream or rust-coloured surfaces. They have been flattened by earth movements, while the siliceous pebbles have retained their original shapes. This conglomerate is well seen on the west side of the little burn just north of Stronefield and on Eilean nam Muc. These two exposures must lie, approximately at any rate, on the same horizon, as an obvious synclinal fold occupies the interval between them. A similar bed is found, as already noticed, on the shore near the mouth of the Baranlongart Burn, to the east of Loch Caolisport. In the western exposures, now under consideration, the conglomerate is associated with abundant quartzite bands, while on the opposite shore quartzite is less abundant. Of course if the conglomerate exposures on the two sides of the Loch are on one and the same horizon, then the threefold division, adopted in the central district, or at least its application to the two southern districts, loses all stratigraphical significance. G. W. G.

The conglomerate is seen again in the Point of Knap at Port an Aomaidh, whence it has been traced inland for a considerable distance, while another outcrop is crossed by a wall half a mile due south of Balimore. The conglomerate here has a matrix of foliated calcareous schist with clastic grains of quartz, which contains pebbles and subangular fragments of a light fawn-coloured limestone, and also pieces of black and white limestone, blue quartz, phyllite and quartzite: the fawn-coloured limestone is the chief constituent. The conglomerate is in places 5 or 6 ft. thick, but varies from this to a few inches at the coast, while locally it is quite unrepresented. It is associated with fine-grained, white and greyish brown quartzites, which make an outcrop for about 1½ mile inland from Port an Aomaidh.

To the east of this quartzite outcrop, from Muileann Eiteag Bagh to the Point of Knap, calcareous phyllites are exposed along the steep rocky cliffs, and sometimes show fine isoclinal folding. North and south of Port an Aomaidh the phyllites near the western edge of the quartzite are very calcareous, with bands of white limestone.

On the north side of the epidiorite mass of Eilean Naomhachd, and as far as Port Ban, similar limy and sandy phyllites, with thin quartzose bands, are well exposed along the rocky shore. Here there are many fine examples of the phenomena produced when hard and soft beds are rapidly folded together.

From Port Ban the phyllites, when traced inland, extend apparently to the head of the Kilmory Burn, well within the area occupied in the main by the Loch Awe Quartzite; superficial deposits, however, make the boundaries shown on the map somewhat uncertain. The phyllites, at the foot of Cnoc Stighseir, appear to pitch below the Loch Awe Quartzite. Farther north another similar extension of the phyllites is occupied by the valley of the Abhainn Mhor.

Beyond this, in the heart of the quartzite country, there are a few isolated outcrops of limy phyllites to the north and south of Castle Sween and along the shore between Creag a' Mhadaidh and Dunrostan. Between the latter and Loch na Fola it is highly probable that the majority of the long narrow hollows, filled with

peat or occupied by lochans, cover beds of this character. In the case of some of these comparatively small and isolated outcrops it is likely that the phyllites belong to the Loch Awe Group, for phyllitic intercalations are well known in this position. J. S. G. W.

Epidiorite intrusions are plentifully distributed throughout the whole south-western area, and by their folding, well displayed to the north of Muileann Eiteag Bagh, illustrate the reduplication characteristic of the district. G. W. G.

CHAPTER VII.

THE METAMORPHIC ROCKS OF THE MAINLAND.—(*Continued*)

VIII.—The Loch Awe Group.

GENERAL DESCRIPTION.

The remainder of the mainland, lying roughly north-west of a line joining the north-east corner of Sheet 28 to Port Ban, near the Point of Knap, is occupied by rocks of the Loch Awe Group.* The types recognised in this group include quartzites, limestones, slates and conglomerates. Many of the quartzites are highly pebbly, with large grains of blue and white quartz and fresh felspar; according to Dr. Flett, who has examined slides (5534, 5695, 9059–9061, 10678, 10791) of coarse Loch Awe grits from various localities, the felspar pebbles include microcline, orthoclase (often perthitic) and oligoclase in decreasing order of abundance; this contrasts with the predominance of oligoclase in the grits of the Beinn Bheula Schists etc., originally recognised by Dr. Teall. The limestones of the Loch Awe Group are in many cases dark grey, blue or black, sometimes pure and fine-grained, but more often somewhat sandy, and, in one outcrop, oolitic; other limestones, of the same colours and general characters, are distinguished by the presence of large pebbles of quartz and felspar identical in appearance with those of the pebbly quartzite; other limestones, again, are very sandy and of a pale grey tint; a good many of the black beds appear to be dolomite rather than limestone, and weather with rusty surfaces. The slates of the Loch Awe Group, like the limestones, are often black, and include both pebbly and non-pebbly varieties; in other cases they are grey. Transitional types of every grade of composition link the non-calcareous slates with the limestones already described. The conglomerates of the Loch Awe Group may, as a rule, be regarded as unusually coarse varieties of pebbly quartzite, limestone or slate. The pebbles, other than quartz and felspar, are generally derived from local sources, and consist of limestone, slate, quartzite and epidiorite, as the case may be. One conglomerate exposure is described below, however, which contains quartz-syenite boulders of the kind found in the conglomerates† of Schichallion, Islay and the Isles of the Sea (Garvelloch). The source of these boulders is quite unknown.

A point of prime importance in the geology of this district is the

* Founded by J. B. Hill, "On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe," *Quart. Journ. Geol. Soc.*, 1899, vol. lv. pp. 470–493.

† B. N. Peach, *Sum. Prog. Geol. Survey* for 1903 (1904) p. 68.

Pillow Lava. An Aird.

occurrence of undoubted pillow lavas* associated with the black slate and limestones of the Loch Awe Group (Plate III). The successful study of these rocks has depended largely upon their very low state of metamorphism. In traversing the outcrops of the various rock groups, from the Green Beds at Tarbert (Sheet 29), for instance, to the Loch Awe Group at Tayvallich (Sheet 28), the degree of metamorphism decreases gradually towards the north-west, so that, starting with well-crystallised schists, one reaches eventually rocks which can scarcely be termed metamorphic at all. This interesting phenomenon has been made the subject of a special paper by Mr. Hill (quoted above), who dealt with the adjoining Loch Awe district, where he was further able to point to an increasing metamorphism along the strike, and show that strata, which, in Knapdale, are little more than cleaved, actually pass into crystalline schists when followed towards the north-east. In Sheet 28 one may remember, as a rough generalisation in relation to the metamorphism of the district, that secondary biotite is readily recognised with the naked eye in the rocks lying east, but not west, of the north-west boundary of the Erins Quartzite.

There are many points of stratigraphical interest raised in regard to the Loch Awe Group. In the first place, we may inquire into the evidence which this district furnishes regarding the relation of the Loch Awe and Ardrishaig Groups. In the second place, we may study the inter-relations of the various rock types of sediment which have been included together under the title of the Loch Awe Group.

These questions are most conveniently answered by abandoning the custom hitherto followed of describing the districts from north-east to south-west. First, the interesting section of Kilmory Bay will be described, where Mr. Wilson † has shown that the Ardrishaig Series passes in folds under a conglomeratic quartzite, which marks the oncoming of the Loch Awe Group. This continues the dominant ‡ structural feature of the Southern Highlands, which may be described as an upward succession of superposition from the Highland Border northwards.

The Kilmory section, as will be shown in the sequel, also furnishes evidence in favour of the generally accepted view that the quartzite is of later date than the Ardrishaig Group.

Having discussed this important section, attention will next be turned to the Tayvallich peninsula on the other side of Loch Sween. Here it is that the relations of the black slates and limestones, on the one hand, and the quartzites, on the other, can be most profitably studied. All agree that the two former hang closely together, and the writers,§ basing their position upon fragments of black slate and limestone not uncommonly found in the pebbly quartzites, were originally led to the conclusion that the quartzites belonged to a later formation than their associates.

Closer study, however, has led to a revision of this opinion. It was found that the structure and succession of the district could be

* B. N. Peach, *op. cit.*, p. 69.

† *Sum. Prog. Geol. Survey* for 1904 (1905) p. 67.

‡ It is unnecessary here to discuss the interesting and important structures elucidated by Mr. Clough in Cowal.

§ *Sum. Prog. Geol. Survey* for 1903 (1904) p. 68.

unravelled in spite of its minor complications. Three main results followed from this renewed study:—

(1) The separation of the black slate and limestone from the quartzite is far from complete. There is an important marginal zone characterised by alternations of quartzites, conglomerates, gritty sediments, black slates and limestones. The fragments found in any particular conglomeratic bed may in general have been derived, so far as we can judge, from the one side or the other. After examination in the field it was found necessary to put aside the conglomerate evidence, as a guide to the original sequence of the deposits in this district.

(2) The quartzite subdivision was found to pitch southwards beneath the black slate and limestone subdivision * (Fig 3).

(3) The superposition of the latter is in all probability natural, and not due to inversion, since its associated volcanic rocks have every appearance of being right side up. Evidence for this conclusion is afforded by the contrast between the scoriaceous tops and the compact bases of the two lowest lavas exposed in the type section on the west coast, in the bay south of Port an Sgadain. It will be recognised that the Kilmory and Tayvallich sections agree. In the

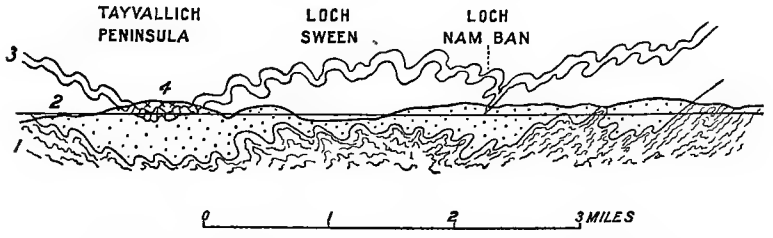


FIG. 1.—Generalised Section across Outcrop of Loch Awe Group.

4. Volcanic Rocks.
3. Black Slate and Limestone. } Loch Awe Group.
2. Quartzite.
1. Ardrishaig Phyllites.

Kilmory section the Ardrishaig Phyllites are seen passing in folds beneath the Quartzite Group. In the Tayvallich section the quartzite is seen passing in folds beneath the Black Slate and Limestone Division. Moreover, in the former section the evidence suggests, and in the latter almost proves, that the structural superposition corresponds with the original stratigraphical order of succession.

It seems justifiable, then, to read the whole of the Loch Awe Group, as exposed in Sheet 28, in the light of these two sections (Fig 1). Thus it is probable that the quartzite in all its folded outcrop is underlain by the Ardrishaig Phyllites. It is also probable, although there is no field evidence to prove this, that the isoclinal folds of black slates and limestones running south-west from Loch an Add to Loch nam Ban are really synclines.

It will further be seen that the modification of view, in regard

* In the Dalmally country Mr. Hill has clearly shown that black slates and limestones are well developed between the Loch Awe Quartzite and the Ardrishaig Phyllites; this we take to be a further example of the recurrence of black slate in different stratigraphical horizons in the Loch Awe Group.

to the Loch Awe sequence in Sheet 28, probably entails a similar modification in the interpretation which one of us, in common with other writers, has placed upon the district to the north. It should be noticed, however, that the fundamental position taken up by Mr. Hill, namely, that the Loch Awe Group lies in a crumpled syncline of Ardrishaig Phyllites, and that it is a younger formation than the latter is very strongly confirmed by the new interpretation put upon the Tayvallich peninsula.

It would be unnecessary to go beyond this, were it not that the relations of the Loch Awe Group in Argyllshire have been used in support of the theory of the "unconformable quartzite" in Perthshire and elsewhere. The writers are now of the opinion that the change of front in the Tayvallich district strengthens, by analogy, the alternative interpretation of the Perthshire sections, which has for years been identified with the name of Mr. Barrow.*

Mr. Hill, who, as already stated, founded the Loch Awe Group, furnishes below a discussion of the position now adopted in regard to the Tayvallich evidence as affecting the general interpretation of the Loch Awe sequence. B. N. P., E. B. B.

The group was described in 1899 as representing a threefold division of limestone, black slate and quartzite in ascending sequence as named. It was recognised, however, that the limestone did not always conform strictly to a definite stratigraphical position, and that slate sometimes occurred at higher horizons between the quartzite bands. In spite, however, of such irregularities in the sequence, the writer placed the main limestone and black slate divisions below the quartzite, and considered repetitions of these lithological types, at higher horizons, to represent subordinate bands. This conclusion was arrived at after studying the marginal relations of the Ardrishaig and Loch Awe Groups for a distance of over 40 miles from Glen Orchy to North Knapdale. The boundary shows a marked lithological change in passing from north-east to south-west: whereas in the neighbourhood of Dalmally there is an extensive development of black slate and limestone interposed between the Ardrishaig Phyllites and the Loch Awe Grit, from that region to the Crinan Canal the black slate is but feebly represented, and the limestone has often dwindled to insignificant bands, while to the south-west of the Canal both members have actually disappeared, and the Loch Awe Grit is resting directly on the Ardrishaig Phyllites. The evidence along this line is clear that the Loch Awe Grit has overlapped the underlying black slate and limestone, and in the *Geological Survey Memoir* on Mid-Argyll it was pointed out that crustal oscillation resulted also in a certain amount of contemporaneous erosion. In the light of this evidence, the writer considered that the extensive development of limestone and black slate in the Loch Awe basin to the west of the boundary of the group represented the basal members that are so largely exposed at Dalmally.

The recent mapping of the Tayvallich peninsula suggests that in that locality a limestone corresponding in character to the main Loch Awe limestone, and associated with the typical black slate, is

* Cf. Sir A. Geikie, Anniversary Address, *Quart. Journ. Geol. Soc.*, 1891, vol. xlvii, p. 74.

underlain by quartzite of the Loch Awe type. On the one hand (*a*), it is possible that the Tayvallich limestone represents a local thickening of one of the subordinate limestone bands that occur within the quartzite series, as both the limestone and black slate of the Loch Awe Group are subject to rapid lateral change. On the other hand (*b*), the limestone of Tayvallich may represent the main Loch Awe limestone so extensively developed in the district to the north-east, in which case it follows that the latter is distinct from the limestone of Dalmally, and that there are two important limestones in the Loch Awe and Dalmally district, both associated with black slate, the one occurring below the quartzite, and the other at a higher horizon, but whether the latter divides the quartzite or entirely overlies it is uncertain.

At the present time it is by no means certain which of the two hypotheses (*a*) and (*b*) is correct, as the interpretation of the structures in adjacent areas do not harmonise. Moreover, the introduction of a second association of limestone and black slate of similar magnitude to that occupying the base of the group does not present such a simple sequence as the threefold division originally presented, and until the hypothesis of the double sequence is supported by further evidence the writer considers it safer to adhere to his original grouping. J. B. H.

The remaining points of stratigraphical interest may be dealt with very briefly.

The limestone continuously traced by Mr. Hill at the margin of the Loch Awe and Ardrishaig Groups throughout Mid-Argyllshire has not been recognised in Sheet 28. It is doubtful whether it ever was deposited in this district, or whether, on the other hand, it was deposited and then denuded before the quartzite was laid down.

Another point, upon which a word or two may be said, is the possibility of splitting up the quartzite itself into groups. In the district to the north (Sheet 36), an exceptionally clear coast section of intercalated fine-grained pebbly quartzites, sandy grey limestones and phyllites, exposed at Ardnoe Point, near Crinan, was taken as typical of a special subdivision of the Loch Awe Group. A similar association of strata is known at several points in the present district, and in many cases it is probable that this indicates the repetition of the "Ardnoe Beds" by folding; but it has not been considered wise to continue the use of the name in the description of these occurrences, since it implies a more definite knowledge than has at present been attained. In particular, it is necessary to state that the writers no longer maintain a strict dual subdivision into "Ardnoe Beds" and "Pebbly Quartzite."

The structure of the district containing the Loch Awe Group in Sheet 28 is a continuation of the fan or pseudo-fan, the continuation of which has been described many times over in its continuation across the rest of the Central Highlands.* Macculloch records its existence in this particular district, saying that "there is a line of

* "A Description of the Western Islands of Scotland, including the Isle of Man," 1819, vol. ii. p. 288.

vertical beds towards which the strata converge on each side, both from the south-eastern and north-western boundaries."

In nature, of course, the line is rather vague, being more correctly designated as a narrow belt where both bedding and cleavage are extremely steep or vertical. This belt is roughly defined by the eastern shores of Loch Sween. For some miles to the south-east of this belt the prevalent dip of bedding and foliation is towards the north-west, and *vice versa*. There is also a tendency for the angles of inclination to be higher near the central belt than at a distance, but this does not preclude the existence of many open anticlines and synclines in the former position, and such are, in fact, very characteristic of the portion of Knapdale lying west of the central belt, *e.g.* the Tayvallich peninsula.

Sharpe's * great paper on the "Arrangement of the Foliation and Cleavage of the Rocks of the North of Scotland" may be passed over here, since it does not deal with Knapdale in particular, but reference should be made to Dr. Jamieson's † early representation of the fan as illustrating clearly the simple syncline interpretation which was at first adopted. The additional complications attendant upon the presence of isoclinal folding were probably not realised till Professor Lapworth had inaugurated his classical researches into the tectonics of other folded regions of Scotland. It was not long, however, before Professor Lapworth's teaching made itself felt,‡ but at the same time Mr. Hill, Mr. Macnair, Dr. Peach and other workers, who discard the old hypothesis of a simple syncline, still regard the fan as a complex crumpled trough bringing down the Loch Awe Group into the heart of the Ardrishaig series. This interpretation, founded originally upon the evidence afforded by adjoining districts to the north-east, has now been immensely strengthened by the structural relations described above in connection with the Tayvallich peninsula (Fig. 1). B. N. P., E. B. B.

LOCAL DETAILS.

Kilmory Bay to Eas Daltot.—At Port Ban the Ardrishaig Phyllite Group dips steeply north-west beneath conglomeratic grits of the Loch Awe Group. It is well known that a dip, such as that observed here, in a shallow section in a region of isoclinal folding, does not convey very much information regarding structural relations; fortunately, however, Kilmory Bay, immediately to the north of Port Ban, throws a further light upon the subject; along its eastern shores a heterogeneous group of strata is exposed, which is a good representative of the "Ardnoe type" of the Loch Awe Group, and markedly distinct in character from the adjacent marginal grits of Port Ban. The rocks of this Kilmory section are greatly contorted about axes having the usual N.N.E. trend; however, they are also affected by a marked N.N.E. pitch, so that outcrops of the various beds zigzag along, nearly parallel to the shore, and roughly at right angles to the trend of the folds. It is thus possible to examine the folds in cross-section, and to determine the order of superposition of

* *Phil. Trans.*, 1852, vol. cxiii. p. 445.

† "The Structure of the South-West Highlands of Scotland," *Quart. Journ. Geol. Soc.*, 1861, vol. xvii. diagram, p. 135.

‡ Cf. J. B. Hill, *Quart. Journ. Geol. Soc.*, 1899, vol. lv. p. 475; and P. Macnair, "The Building of the Grampians," *Roy. Phil. Soc. Glasgow*, 1903, vol. xxxiv. p. 147, etc.

the beds involved in them. The order found is enough to prove, without introducing any hypothesis, that *the Loch Awe Group overlies the Ardrishaig Group in a series of folds* (Fig. 2).

In the Kilmory Bay exposures the basement bed of the Loch Awe Group, exposed on the north side of Port Ban, is about 16 ft. thick, and rests on a thin brown limestone. For the most part it is a pebbly quartzite with bands of fine conglomerate dispersed at intervals throughout, one above the other; a single band may sometimes amount to 2 or 3 ft. in thickness. The pebbles in the conglomeratic seams consist of pellets of grey limestone, lumps of blue and white quartz, white and pink felspar, phyllite and a few black schist fragments, all set in a pebbly quartzite matrix.

The individual bands of conglomerate have in every instance a well-defined base-line, and the pebbles come in thickly at the very start; but they decrease in number upwards quite gradually, so that, in this direction, the conglomeratic bands have no definite boundary against the containing pebbly quartzite; the tops and bottoms of the conglomerate beds are thus strongly contrasted, and the contrast is of the type one meets with, not uncommonly, in unfolded conglomerates. In fact, it is exceedingly difficult to escape the inference that *these conglomeratic seams are right way up.* If this be a true deduction, it follows at once that the Loch Awe Group is of later date than the Ardrishaig Group. It may be mentioned that heretofore this

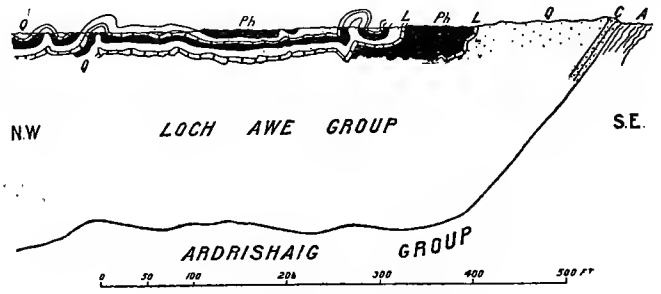


FIG. 2.—Section in Kilmory Bay.

Q. Quartzite.
Ph. Phyllite.
L. Limestone.
C. Conglomerate.
A. Ardrishaig Phyllite Series.

} Loch Awe Group.

relationship has been very generally assumed by geologists, but, at the same time, it is one which is rarely supported by definite evidence.

A few further details may be added in regard to this important section. The conglomeratic quartzite of Port Ban passes north-west under about 120 ft. of light brown or grey gritty quartzite, which becomes finer in its upper portion. This is followed by the heterogeneous group (Ardnoe type) of Kilmory Bay. Quartzite plays a somewhat subordinate rôle here, and is fine-grained, not coarsely pebbly. Three massive beds of it, each of them several feet thick, have been traced through the various folds. They are separated by limy phyllites, impure limestones and dark grey phyllites, containing scattered pebbles of quartz,

A continuation of this alternating series occupies the shore for some distance north of the section where the details of the folding are so clearly displayed.

Inland exposures show that the conglomeratic bed maintains its characters for a distance of about 4 miles along the strike.

North of Fearnoch a fine face is exposed, where the average size of the pebbles is about 1½ in., while some well-rounded blocks of phyllite and limestone are 6 in. in diameter. J. S. G. W.

In the area adjoining the Abhainn Mhor there is an infold of the Loch Awe quartzite. The pebbly character of the bed is generally well seen and is more noticeable towards its base. In many places the individual pebbles and grains have been drawn out by earth movements, and the clastic structures have been obliterated.

Bands rich in limestone pebbles are frequent, and are not confined to any particular bed. These pebbles have also suffered from movement, and the cracks in them are filled with veins of quartz. A section across the fold is exposed in the gorge of the Abhainn Mhor, about a quarter of a mile north of the Kilmory Road Bridge, where the two limbs may be seen dipping in towards one another. A good deal of movement has taken place along the actual junction, and the mutual relations of the quartzite and the phyllites are obscured.

J. S. G. W., G. W. G.

Conglomeratic exposures occur at intervals, near the margin of the Loch Awe Group, as far to the north as the Cruinn Loch. Beyond this, towards Eas Daltot, the horizon loses its conglomeratic character, passing into a coarse pebbly grit with pebbles of white and blue quartz and merely an occasional fragment of limestone. These coarse pebbly bands, though seen to the north of the Dubh Loch, do not reach Eas Daltot itself.

West of the main margin conglomerate exposures are not known; the mutual relations of the pebbly quartzite and subordinate phyllite outcrops of this district are none too clearly understood. Epidiorite sills are remarkably abundant everywhere. J. S. G. W.

Tayvallich Peninsula.—Under this title are included all the promontories west of Loch Sween and south of Carsaig Bay and Loch a' Bhealaich, together with the adjacent islands, of which Danna is the most important. The rocks of the Loch Awe Group, in this area, naturally fall into two groups: (1) quartzites, which form the bulk of the sedimentary rocks in the northern and eastern parts of the district, and (2) black slates and limestones, which preponderate in the remaining western tract. Schistose igneous rocks are strongly developed in connection with both groups. Those associated with the quartzites are intrusive sills, so far as is known, and in the main basic, but with leucocratic varieties. Those that occur with the limestone and slates, on the other hand, are mostly volcanic, consisting of basic lavas with subordinate tuffs.

The structural relations of the two sedimentary groups are manifest in the northern part of the area where, as will be described in the sequel, the Limestone-Slate Group with its associated lavas clearly overlies the Quartzite Group with its intrusive sills. The

rocks of the area are sharply folded, in the manner usual in the region, about axes trending N.N.E. and S.S.W., so that the order of the superposition of the beds is only made apparent owing to a marked pitch of the axes of the folds towards the S.S.W. in the northern part of the area. The Quartzite Group is thus carried to the southward underneath the overlying slates, limestones and volcanic rocks, which cross the peninsula from the Sound of Jura inwards to the Linne Mhuirich in the form of an escarpment facing the north, complicated by minor folding.

While the sedimentary rocks may be divided into the two groups already mentioned, there is no sharp line of separation: an intermediate zone is present, characterised by a conspicuous interbedding of the various rock types.

The details of the structure and succession will best be understood by reference to the sketch map (Fig. 3), which shows the northern end of the compound syncline of the Limestone-Slate-Volcanic Group embraced by the underlying Quartzite Division.

Various minor subdivisions of the groups can be followed more or less successfully from fold to fold, and have been numbered on the map in accordance with their order of superposition, as determined along the pitch of the folds.

A convenient starting-point for their study is the prominent

Explanation of Fig. 3.

	Ft.
C. Main Volcanic Zone forming an escarpment facing north and running from sea to sea; the escarpment is complicated by minor folds ..	—
B. Black and grey slates	50
Black limestones	—
Black pebbly limestone (a layer towards the top brecciaform with abundant fragments of black limestone and slaggy epidiorite).. ..	20
Black slates	30
A. Somewhat vesicular non-porphyrite epidiorite	30
5. Dark grey and black slates	(?)
Fine pebbly grit	20
Black slates, generally absent; a gritty bed in these slates contains pebbles of black and oolitic grey limestones. There are also nodules of rusty-weathering black limestone (?dolomite) in the bed immediately adjoining the gritty band	10
4. Non-porphyritic epidiorite (inconstant but inland very thick) with somewhat vesicular margins	10
3. Sandy grey and good black slates	30
Coarse pebbly grit	20
Grey sandy slates	10
Non-porphyritic epidiorite, somewhat vesicular at both margins, but especially so at top	15
Sandy grey limestones and slates	20
2. Porphyritic epidiorite	1
Sandy slate	1
Non-porphyritic epidiorite, base not seen, somewhat vesicular top ..	30
1. Thick massive pebbly quarztite	—
Grey slate	—
Pebbly quartzite	—

The structure between Creag nam Bunneag and the coast-line to the north is not clear, but the epidiorite forming its eastern portion seems to be (4) of the table, and the coarse massive pebbly grit to the west either the grit in group 3, or that in group 5, in which case the epidiorite is transgressive. Group B is undoubtedly an upward continuation of group 5.

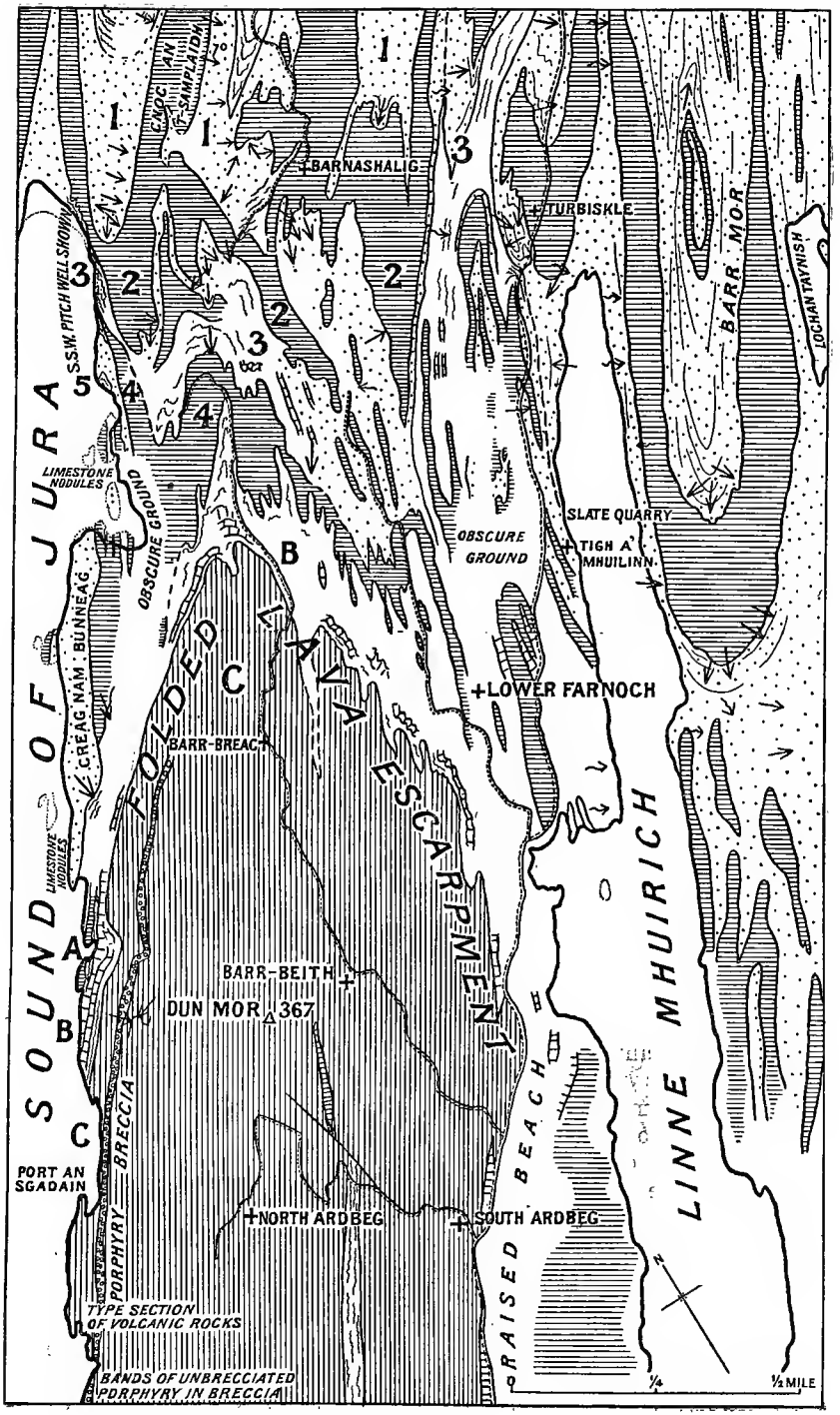


FIG. 3.—Sketch Map of a Portion of the Tayvallich Peninsula.

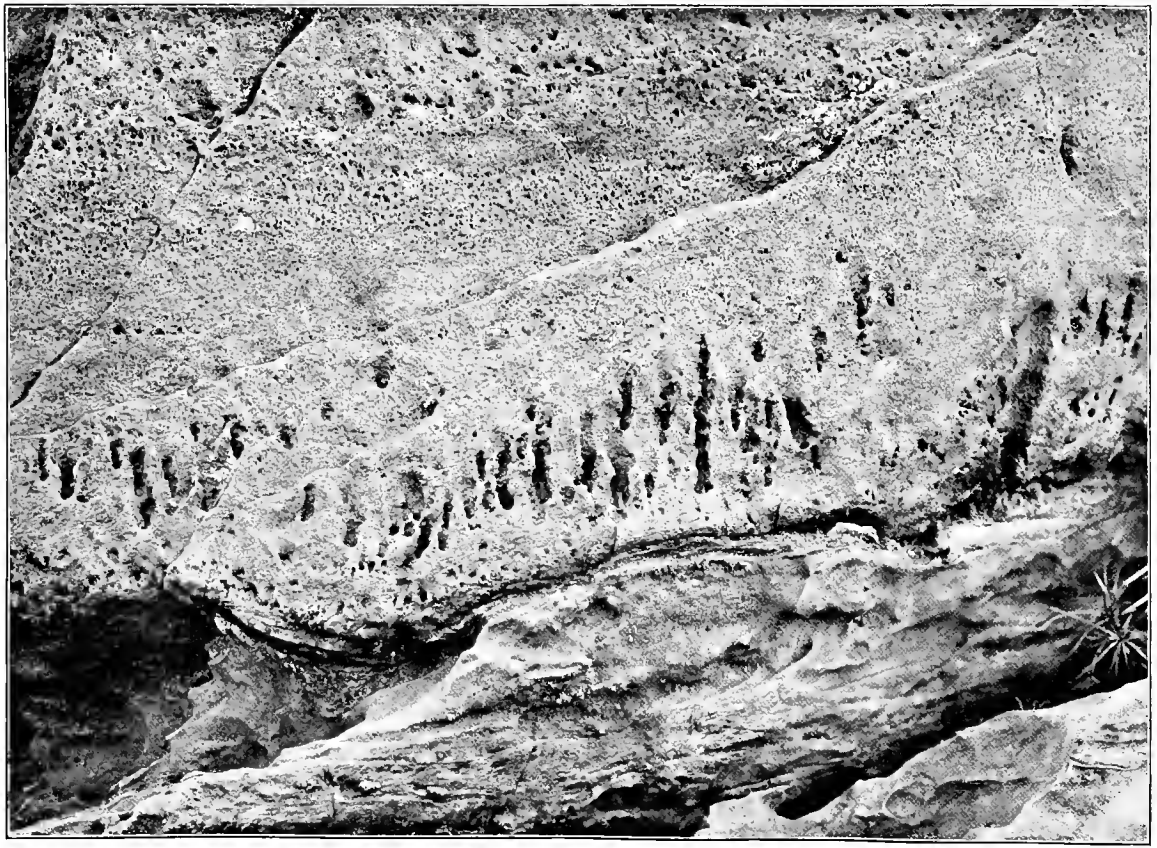
anticlinal fold to the west of Cnoc an t-Samhlaidh composed of massive pebbly quartzite (1), which to the north, just within the limit of the map, has an important intercalation of soft grey slates. Following southward along the axis of this fold the pebbly quartzites pitch under the sill of epidiorite which forms the crest of the Cnoc an t-Samhlaidh ridge, and can also be traced down to the shore on the western limb of the anticline. Onward the succession is best studied in the coast section where the various subdivisions are seen to be thrown into sharp steep folds, often isoclinal and in almost every case pitching towards the S.S.W. It is true that the coast section is not so full as to be absolutely convincing, but its indications of an upward structural succession are confirmed beyond doubt in a whole series of inland exposures. The southerly pitch which is so important in this district is very beautifully exhibited, for instance, in some folds of quartzite by the roadside at Turbiskle.

The list given in the explanation, facing the map (Fig. 3), has been drawn up to illustrate approximately the nature of the section met with in ascending order as the folds are followed south along the coast. The chief features are the intercalations of conglomerates, quartzites and pebbly beds of various kinds, with slates and dark grey or black limestones (among which dolomite is probably well represented). It was not found possible to determine from the nature or relations of the conglomerate beds whether or no the ascending structural succession agrees with the original stratigraphical sequence. The occurrence of occasional oolitic-limestone pebbles in a conglomeratic bed (5) is certainly suggestive of a big inversion, since the only oolitic exposure known anywhere in this district, in Eilean Mor, is, in all probability, upon a structurally higher horizon than this conglomeratic bed. In the light of the very definite evidence to be brought forward presently, however, that this sequence is not inverted, it seems necessary to postulate the existence of another oolitic bed somewhere in the neighbourhood on a lower horizon. B. N. P., E. B. B.

The escarpment of the main volcanic zone (group C, Fig. 3) can be readily followed. It has the form of a V with the point directed north-east, and the superposition of the lavas upon the limestones and slates of group B is particularly clear. The volcanic zone is unmistakably distinct from anything underlying it.* Though some of the lower epidiorite sheets may, it is true, be lavas, they do not resemble the pillowy and slaggy beds which, with thin bands of ash and intercalations of black slate and limestone, constitute the group now under consideration.

It is the striking contrast between the tops and bottoms of the lowest lavas of this subdivision, as exposed in the bay to the south of Port an Sgadain, that furnishes the key to the original stratigraphical succession of this difficult district. In this section, which is part of the escarpment referred to above, the lavas certainly appear to be right way up; therefore, the deduction is, they are the latest formed rocks of the series so far considered. The section in the

* The petrology of the volcanic group is discussed with that of the intrusive epidiorites in Chapter VIII.



Pipe Amygdules in Base of Lava resting on Calcareous Tuff. Bay south of Port an Sgadain.

bay on the south side of Port an Sgadain (Fig. 4) may now be decribed in detail.

The lowest lava (*a*) is a dark coloured igneous rock, resting upon a series of thin banded dark limestones and phyllites, which are only visible at low tide. The upper surface of this lava is remarkably rugged and consists entirely of pillow-shaped masses. The pillows vary in size from large rounded blocks, 14 ft. in diameter, to small spheroids, less than a foot across. They are mostly ellipsoidal, but, where they are in contact one with another, their surfaces may be flattened, or the convex side of one may fit closely into a concave depression in another. Occasionally a transverse section of a pillow occurs, showing the highly vesicular nature of these structures. The steam cavities lie in concentric bands or zones, parallel to the surface, and separated by less vesicular rock. Central cavities are sometimes present, but they do not seem to be a constant or significant feature.

Only the upper part of this lava is pillowy. The whole bed is about 20 ft. thick, while the pillowy upper portion is not much more than 8 ft. thick. The pillows are piled up in several rows one on top of another. The lower portion of the lava is irregularly jointed and contains comparatively few steam cavities.

Where it has not been subsequently eroded away, dark fine-

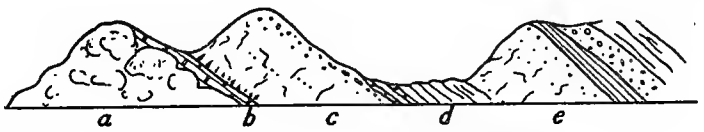


Fig. 4.—Volcanic Section, S. of Port an Sgadain.

grained impure bedded limestone or dolomite occupies the interspaces between the pillows. It contains occasional layers of shaly material with broken crystals of felspar, indicating a possible admixture of ash. It dips 40° to the east and passes under a bed of similar dark dolomite (*b*), which lies between the lava just described and the succeeding one. The thickness of this dolomite varies from a few inches to 3 or 4 ft., and its outcrop can be traced along the strike for 300 or 400 yds. It interdigitates with thin films of black slate and contains patches of ashy material in the form of scattered fine grey volcanic débris.

The next member of the series, in ascending order, is a lava flow (*c*) from 15 to 20 ft. thick. Its base conforms exactly with the bedding of the underlying dolomite. It is not a pillowy lava, but the contrast of its top and bottom portions is almost as marked as in the proceeding case.

It is a highly vesicular rock, especially in its upper portion, which is rendered porous by the abundance of large and small steam cavities. The central part of the flow is traversed by parallel bands of spherical vesicles, while the base is characterised by large steam tubes, "pipe-amygdules," an inch or more in diameter and sometimes a foot in length (Plate IV.). These pipe-amygdules are slightly tortuous, and are set approximately at right angles to the base of the lava. They were probably produced by the uprise

of steam from the moist sediment below at the time when the latter was overwhelmed beneath the lava stream.*

On the back of this lava there lies a thin black dolomitic limestone (*d*) which fills all irregularities on its surface and is not itself baked. It shows fine bedding, and consists mainly of small rhombohedra of dolomite, with grains of quartz and felspar, iron oxides, carbonaceous matter and scales of white mica and chlorite. It is succeeded by well-bedded phyllites 15 to 20 ft. thick, with thin arenaceous and calcareous bands an inch or so thick.

On these lies another lava (*e*) 8 or 10 ft. thick. It is highly vesicular throughout and contains parallel bands of steam cavities. Its base rests on the sediments with perfect conformity, and its upper surface is quite slaggy. The rock has, however, suffered more from crushing and deformation than those below.

A mass of banded ashy-looking sediment follows, containing three or four sheets of epidiorite. Passing over these outcrops, a bed of porphyry breccia is encountered, and upon the other side of this a massive epidiorite; then follows another and thicker breccia containing numerous large fragments of pink porphyry set in a fine-grained matrix.

This breccia possesses thoroughly distinctive characters and can be traced at intervals along the coast, south to Rudha Riabhag, where it finally goes out to sea. It can also be followed for more than a mile to the north. It is clearly interbedded with the volcanic series, but its exact nature is problematical. At first it seemed probable that it was an ash or agglomerate, but there is at least one item of field evidence which renders the ash hypothesis difficult; a third of a mile south of Port an Sgadain (at a point indicated by a note in Fig. 3), a section exists where one or two thin unbrecciated bands of the porphyry alternate with the brecciated portion, which latter otherwise retains its normal characters.

In like manner, rather less than 2 miles south of Port an Sgadain (see note on one-inch map 28), at a point where one might expect the breccia to catch on to the coast, there are, instead, two close parallel bands of the porphyry in a massive condition.

It seems probable then, or at least possible, that the bed is one of those peculiar flow breccias which are so notoriously difficult to separate from true ashes. The petrological nature of the rock fragments points to a hypabyssal rather than superficial origin for the bed.

Another mode of accounting for this breccia is to assume that it is a sill crushed to fragments subsequent to its consolidation. This hypothesis is not favoured, for the following reasons:—

1. The occurrence of unbrecciated bands of the porphyry in one section of the breccia.

2. The occurrence of sedimentary seams enveloped in the breccia and traceable unbroken for yards.

3. The absence of brecciation of the rocks at the margin of the bed, and its freedom from foreign fragments (in the sections neighbouring Port an Sgadain).

4. The strongly banded nature of the breccia, which is less difficult to understand in the light of the flow-breccia than the

* Cf. A. L. Du Toit, "Pipe-amygdaloids," *Geol. Mag.*, 1907, p. 13.

crush-breccia hypothesis. This feature, of course, furnishes a good argument in favour of the view that the breccia may after all be a bedded ash.

The account given above will serve as a general introduction to the volcanic rocks of the Tayvallich peninsula. The area occupied by the group, with its associated sediments, evidently widens to the south. No better pillow lavas are known than those which form the islands of Carraig an Daimh and Dubh Sgeir, in the Sound of Jura, while another good example makes its appearance in Corr Eilean, to the south of Danna.

Within the limits of the outcrop there are several interesting exposures, the connection of which, one with another, is not always very clear. A very small selection are described below.

Pillow structure is especially well shown on the west coast of An Aird (Plate III.) and again south of Sailean na h-Airde.

On the east coast of Sailean na h-Airde there is a curious conglomerate or agglomerate full of lenticular fragments of a peculiar quartzo-felspathic schist, which Dr. Flett has examined microscopically and described as not improbably a baked sediment. The baked appearance is not, however, restricted to the fragments, for the matrix of these breccia beds has also an indurated aspect in the field. Occasionally blocks of vesicular epidiorite are common in certain layers. This conglomeratic bed appears to be on a considerably higher horizon than the porphyry breccia described in detail above.

An extraordinary conglomerate has been traced along the west shore of Loch na Cille, and is well exposed at the roadside to the north. It is extremely full of fragments of slaggy epidiorite,* but also contains numerous pebbles of white felsite and syenite rather sporadically distributed. The latter is of the type met with in the conglomerates of Islay, Schichallion and the Isles of the Sea.† The fragments are so closely packed that the nature of the matrix is not easy to determine. In places it contains crystals of felspar and strongly resembles a decomposed sheared porphyritic epidiorite full of carbonates. The conglomerate is interbedded between epidiorite to the west and a more or less pebbly blue-grey limestone to the east. The latter is locally richly charged with fragments of slaggy epidiorite.

Eilean Mor is remarkable as the site of the only known exposure of oolitic limestone belonging, as one may fairly say, to the mainland of Argyll, and similar to the dark grey oolitic limestone prominently developed in Islay. At one point the limestone presents most unusual features. It serves as matrix to a thick bed for the most part composed of separate small pillow-shaped masses of

* Mr. Hill, who visited this exposure, is of opinion that the epidiorite fragments, both here and in the Sailean na h-Airde breccia, have been introduced as the result of the crushing which is so much in evidence in this district and is discussed below.

† The petrology of the foreign boulders in the Loch na Cille conglomerate is discussed at the end of this chapter.

epidiorite. It is difficult to regard this bed as a pillow lava, for the pillows are not in contact, one with another. It is equally difficult to regard it as a crush-conglomerate, for there is nothing to suggest that the oolitic matrix has been introduced dynamically. It is more likely that it is a true conglomerate which owes much of its peculiar character to direct volcanic action.

The Tayvallich peninsula furnishes an unusually large number of "conglomeratic" exposures of doubtful origin—sedimentary or dynamic.* A good many of these probably represent true sedimentary conglomerates subjected to intense shearing, which has superinduced dynamic features upon the original sedimentary structures, thereby rendering their nature doubtful. In other cases it appears that folding and shearing have given rise to crush-conglomerates *de novo*. An example, which, upon careful examination, seemed to be a genuine crush-conglomerate, is exposed a little east of the jetty on the east shore of Loch na Cille.

A quarter of a mile south of the jetty just alluded to, there is a good exposure of pebbly quartzite resting on blue limestone and containing fragments of the same. This was one of the sections originally regarded as critical in fixing the age of the quartzite series in respect to the limestone. According to the reading at present adopted, however, it seems that this quartzite bed must be an intercalation in the limestone group, and much younger than the main mass of quartzite. B. N. P.

The interest of the Tayvallich peninsula is far from exhausted in the account just given, and the geologist who visits its western shores will be well rewarded. As much has been said, however, as space warrants, and the remainder of the Loch Awe series, so far as contained within Sheet 28, will now be briefly described.

West of Caol Scotnish.—This district is the natural northward continuation of the Tayvallich peninsula. It is for the most part constituted of more or less pebbly quartzites folded with epidiorite sills. Even thin beds of black slate are uncommon, but one such is exposed near the northern jetty in Carsaig Bay, and another near Scotnish. Beds of "Ardnoe type" figure prominently in the shore section at the entrance to Loch a' Bhealaich. E. B. B.

East of Caol Scotnish.—The main feature of this district is a median outcrop, entering the Sheet about Loch an Add, which largely consists of black slates and limestones; both the pebbly and non-pebbly varieties of these rocks are well represented. They are associated with bands of epidiorite, but none of the latter have been definitely shown to be lavas. This outcrop of black beds may be described as a tail reaching down from the wide expanse of similar rocks exposed in the Loch Awe district. We are therefore led to expect that it marks the axis of a fold. Detailed mapping has

* Cf. J. B. Hill, "On the Crush-Conglomerates of Argyllshire," *Quart. Journ Geol. Soc.*, 1901, vol. lvii. p. 313.

made this hypothesis almost a certainty, but has not shown whether the supposed fold is a syncline or anticline. The limbs are vertical, or nearly so, and the folding appears to be not only isoclinal, but also very tightly compressed. The Tayvallich evidence certainly suggests that this outcrop marks the axis of a more or less complex syncline. B. N. P., J. B. H.

In the area east of this central outcrop, the most interesting feature is the absence from the Ardrishaig Phyllite border of the limestone which has been so constantly found in that position in Mid-Argyll.

The limestones first met with are seen on the shores of Loch nam Breac Buidhe, and within a quarter of a mile of the boundary. They form thin bands of the impure sandy type, similar to those which occupy the base of the group in the adjacent tract to the north-east. Further to the west, similar outcrops lie in a belt, the central position of which is occupied by the Gleann Loch, and others occur still further north-west on the shores of Loch na Faoilinn. These limestones, however, are confined to narrow bands. The greater part of the tract is represented by grits, the seams of which vary considerably in texture, while phyllite occupies a subordinate position.

Some of the exposures of coarser grits will now be described. About a quarter of a mile south-west of Loch na Faoilinn coarse pebbly zones occur amongst fissile grits. To the south of the Dubh Loch some pebbles are as large as beans, both rounded and sub-angular, while half a mile further to the south-west the coarse bands contain a large proportion of blue quartz grains. To the south of Loch Clachaig certain bands contain pebbles as large as peas, in which clear blue and pink quartz are abundant, and one or two individuals of hornblende were observed. On the hill to the south-west of Cruach nam Fiadh are zones almost entirely composed of blue quartz grains larger than marbles, some of which are stretched, while a little further north felspar is likewise a prominent constituent.

The dips, which gradually become steeper from the south-eastern margin towards the north-west, range approximately from 55° to 80° in the last-named direction. Although the strata do not exhibit the same contortion as the groups that lie to the south-east, isoclinal folding is characteristic, and there is consequently much repetition of the beds, which is especially well brought out by the outcrops of the epidiorite sills.

These intrusions are as profusely distributed as in the adjacent Ardrishaig Phyllite tract to the south-east; some of the individual bands have been traced for a distance of 3 miles to the valley of the Lussa, where their continuity is severed by a big fault. Many of the bands coalesce into a common trunk, while others, for example, the large sill immediately west of Loch Clachaig and that situated on the west of the Dubh Loch, reveal the terminal curvatures of pitching folds. J. B. H.

That part of the district which lies to the west of the central black slate and limestone outcrop, is again mainly composed of

pebbly quartzite and associated epidiorites. It is traversed by the axial belt of the pseudo-fan already described, so that the dips throughout are very steep. Their direction is generally towards the north-west, east of Barr Mor, and towards the south-east, on the other side of that hill.

The Lussa to Eas Daltot.—This district may be called a fault block, but it obviously continues the structures described to the north. The median outcrop of black slates and limestones is, however, more limited and isolated, being restricted to the neighbourhood of Loch nam Ban. The correlation of the black sediment in this instance, with those of the Tayvallich peninsula, is greatly strengthened by their association here with a typical porphyritic pillowy lava. The interspaces between the individual pillows of the lava are often occupied by sediment. The best exposures of the rock lie west of a prominent crag of pebbly limestone about half a mile north-east of the loch.

While it is, therefore, extremely probable that the outcrop occupies the core of a fold, the latter cannot be of a simple type, for there is no repetition of the beds about a central axis; there is some evidence on the ground of a strike fault along the eastern margin of the outcrop, which would account for this discrepancy.

To the east of the median outcrop the main interest centres upon the relations of the quartzite to the Ardrishaig Phyllites. The main boundary runs just to the east of Cruach Lusach. It is much obscured by a number of narrow epidiorite outcrops, but it is still quite clear that the marginal conglomeratic grits, found further south, are unrepresented here. The first beds referable to the Loch Awe Series are fine-grained grits, making a little scar to the north-east of the summit of the Cruach. They are followed to the west by sandy limestones, slates and calc-silicate hornfelses (closely simulating chert) associated with an epidiorite sill. It appears then that, in this section, beds of "Ardnoe type" come into direct contact with the Ardrishaig Phyllites.

West of Cruach Lusach the sedimentary schists consist almost exclusively of massive grits, not very pebbly and generally showing cleavage. They dip north-west at about 60° near the summit of the hill, but are vertical near Creag nan Iallag.

Between the grits and the Creag nan Iallag sill, 100 ft. or so of green phyllites, silky white phyllites, sandy limestones, fine-grained quartzites and white calc-silicate hornfelses are excellently exposed in stream section. They recall at once the group found close to the boundary of the Ardrishaig Series on Cruach Lusach, and are probably the same repeated by isoclinal folding, for still further west in Allt Buidhe we find slaty phyllites which appear to be an infold of the Ardrishaig Group. The presumption in favour of this interpretation is so strong that a fault is suggested on the map to account for the absence, along the ill-exposed western margin of the phyllites, of the Creag nan Iallag sill and the calcareous group.

The outcrop of epidiorite at the south margin of Loch na Craige

Grainde is bordered by a narrow outcrop of a hornfelsed calcareous series like that of Cruach Lusach. It is likely then that, at this point, the very bottom beds of the Loch Awe Group are repeated by folding.

For a space, measured across the strike, of about half a mile west of Loch na Craige Grainde there is nothing of particular interest to note, the country being occupied by outcrops of pebbly quartzite and epidiorite until the black slates and limestones of Loch nam Ban are reached.

The coarse pebbly quartzites, which succeed the Loch nam Ban limestones to the west, are followed by less pebbly varieties, and before reaching the coast several exposures of the "Ardnoe type" are to be seen. On the shore the sections are much clearer, and here, too, the "Ardnoe type" is well developed. This locality gives the impression of frequent isoclinal repetition. Outcrops of epidiorite are well represented. E. B. B.

PETROLOGY OF THE LOCH NA CILLE CONGLOMERATE.*

In a good many places in the Scottish Highlands,† always in more or less close association with quartzite, boulder beds or conglomerates occur containing fragments of coarse-grained granite and syenite. These pebbles are mostly flesh-coloured or grey and are exceedingly rich in alkali felspar, while soda-lime felspars are usually absent. Their femic minerals are decomposed and replaced by biotite, chlorite and quartz in nearly every case. The rocks are often very massive, but brecciated types with cataclastic structure and various kinds of gneiss occur also in this bed. In the little altered exposures of Islay and the Isles of the Sea, it is clear that some of the boulders were gneissose and schistose before they were enclosed in the conglomerate: others were certainly normal igneous rocks at that time and are so still.

The conglomerate at Loch na Cille shows comparatively little foliation, but elsewhere in the Highlands it may pass locally into a conglomerate schist or conglomerate gneiss. The pebbles are of high interest as affording information relative to the composition of that pre-Dalradian land by the degradation of which the sedimentary beds of the Loch Awe Series were built up. Although they may be classified as granites, syenites, nordmarkites and pulaskites, they have all so much in common that there can be little doubt that they all were derived from the same mass. As pebbles of the same type occur also in the boulder bed at Schichallion in Perthshire, this pre-Dalradian granitic and syenitic series may have occupied a considerable area. It is interesting to note that nepheline syenites, in several parts of the world, accompany rocks similar to those under consideration; but though they have been looked for with some care, no trace of them has been discovered in the boulder beds of the Scottish Highlands.

* The field-relations of the conglomerate are described on p. 71.

† J. S. Grant Wilson, "The Geology of the Country round Blair Atholl, Pitlochry, and Aberfeldy," *Mem. Geol. Survey*, 1905, p. 60; S. B. Wilkinson, "The Geology of Islay," *Mem. Geol. Survey*, 1907, Chs. vi. and vii.; B. N. Peach, "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1908, p. 32.

The pink and grey felspars of these rocks are in excellent preservation. They are in all cases alkali felspars; no oligoclase or other soda-lime felspar was observed in them. Coarse microperthite is by far the commonest, the albite forming large irregular patches and veins in a matrix of orthoclase. Orthoclase is also common, but microcline is rare and often is not to be seen in the slides. Albite occurs in small crystals, and there is also much felspar which shows highly complex twinning in two systems at right angles to one another (Plate V. Fig. 4) and may be identified with the checker albite of Becke, to be described in Chapter IX. in connection with the red porphyry which is intrusive into the pillow lavas. The femic minerals are nearly always replaced by dark green chlorite and quartz, and their nature cannot be inferred from the shapes of the pseudomorphs. Deep brown hornblende (barkevikite?) is found in one rock, and its absence from the others probably means that in them there was pyroxene rather than amphibole. Original biotite may also have been present, but though there is a good deal of this mineral in some of the rocks, it is clearly secondary in many of them. A very special feature is the abundance and large size of the crystals of zircon; they are pale brown and often zonal but not pleochroic. Prismatic forms with pyramidal terminations are the commonest. No other Scottish rock contains so many large zircons as these pebbles do.

Structurally they belong to two types. One group is granitoid, with no eumorphic minerals but with large alkali felspars (which always form by far the greater part of the rock) in irregular individuals that have interlocking or dovetailed margins. When quartz is present it is interstitial, and the femic minerals, we may safely infer from the shape of their pseudomorphs, had seldom or never crystalline faces. The other type is porphyritic with phenocrysts of alkali felspar in a trachytic (or orthophyric) groundmass.

Granite Pebbles.—Only one of the specimens is really sufficiently rich in quartz to be called a granite. It is of aplitic character, fine-grained, pink and almost devoid of femic constituents.

Nordmarkite Pebbles.—The majority of the pebbles are nordmarkites or quartz-alkali syenites. They are rather coarsely crystalline, very rich in pink felspar, with green spots which are the remains of femic minerals. In the slides of these rocks the large irregular alkali felspars greatly predominate. Quartz is scanty and interstitial; chlorite, quartz, carbonates, iron oxides and epidote fill the spaces once occupied by pyroxene or amphibole. The zircons are numerous and very large. Deep brown orthite occurs in some of the nordmarkites. Orthoclase and microperthite form by far the larger part of these rocks, but checker albite is abundant in some of them (Plate V. Fig. 4).

Pulaskite Pebbles.—These occur in fair numbers and differ from the nordmarkites only in the absence of primary quartz. They present all the features above described, but seem to have contained more femic minerals than the nordmarkites, as may be inferred from the greater number of pseudomorphs consisting of secondary minerals.

In these rocks there is sometimes a brown biotite, which may be primary. It seems to pass on weathering into deep green chlorite with remarkably strong pleochroism from golden yellow to intense green. In one of these rocks also there are a few crystals of dark brown very pleochroic hornblende, probably barkevikite.

Most of these rocks in the Tayvallich boulder bed are quite massive or show only a feeble development of cataclastic and mortar structures. Sometimes they have been broken, and the quartzose or calcareous matrix of the conglomerate has been driven into the fissures.

Porphyry Pebbles.—Pebbles of pale or dark coloured porphyritic rocks are also common in this conglomerate. They have a considerable resemblance to the syenites, and it seems clear that most of them, at any rate, have the same origin. The development of porphyritic facies at the margins of pulaskite masses, or as dykes in and around them, is sufficiently frequent to make this correlation exceedingly probable. Although quartz occurs in the groundmass of some of these porphyries, it never forms phenocrysts. Alkali felspar (orthoclase, microperthite and albite) are the principal minerals of the first generation. There may also have been femic phenocrysts, but these were scarce and are replaced by calcite, chlorite and quartz. Zircons occur in the porphyries, but are neither so frequent nor so large as those of the syenites. No pyroxene or hornblende has been found in them, but there is deep green, strongly dichroic chlorite, possibly secondary after biotite. A rich brown mica occurs also, clearly secondary in some of the rocks, and it has long, needle-like, pointed forms which instantly suggest the aegirine of the rocks of the tinguaite series. The mode of occurrence also is similar to that of aegirine in dyke-rocks. Some of these porphyries consist almost entirely of alkali felspar in two generations, the groundmass having an orthophyric character. In others there are many patches of secondary products after original ferromagnesian minerals, so that it is certain that many types of dyke-rocks were originally represented in this conglomerate, though in their present state it is not possible to exactly define their relationships. J. S. F.

CHAPTER VIII.

THE METAMORPHIC ROCKS OF THE MAINLAND.—(*Contd.*)

IX.—The Older Igneous Rocks.

FIELD RELATIONS.

Outcrops of epidiorite are distributed over the entire area, with the exception of the tract that forms part of Kintyre, as their south-easterly limit is marked by the horizon of the Loch Tay Limestone. The group includes epidiorite, hornblende schist and chlorite schist. They exhibit variations both as regards composition and structure. Although basic rocks predominate, others rich in felspar are abundant, which may be classed as intermediate. On the broad scale, while the more basic bands lie in the south-eastern part of the area, the less basic seams in which felspar is a prominent constituent are chiefly found further north-west. Some bands are massive throughout and show little schistosity; others again have been completely deformed and converted into fine schists.

Such constant reference has already been made to these igneous rocks in describing the sedimentary schists with which they are associated, that it is unnecessary to repeat here the local details of their distribution. The following descriptions deal mainly with selected examples and with points of general interest.

Epidiorites associated with Loch Tay Limestone, Stonefield Schists and Erins Quartzite (*S. and S.W. of Loch Gilp*).—The dominant type found in association with these sediments is a massive, dark, fine-grained hornblendic rock, frequently mottled owing to an irregular distribution of dark hornblende in a dull greenish matrix: garnets are sometimes recognisable with the naked eye. This dark compact type is characteristically represented by the exposures situated in the vicinity of Cnocan Imheir, to the east of Kilberry. Foliated varieties are also well developed in the south-eastern area, both in association with the more massive outcrops and in independent bands.

While these fine-grained rocks represent the dominant types in the south-east portion of the district, bands of coarser texture are sometimes met with, one of which extends from the coast of Loch Fyne, near Eilean an Dunain, to Abhainn Ghillean (Sheet 28). This rock contains parallel seams thickly studded with green hornblende blades, up to half an inch in length, that lie parallel to the foliation of the rocks, and the felspathic material is similarly disposed. The band is about 50 yds. in width, and, on the crag face between

Meall Reamhar and the stream above mentioned, is seen in transverse section; here large spheroids, about a foot in thickness and from 1 to 3 ft. in length, consisting of coarsely porphyritic rock, are enclosed by thin layers of hornblende schist, the foliation planes of which correspond with the curved surfaces of the spheroids. The appearance somewhat recalls the structure of the pillow lavas, but seems to be due in this case to movement before final consolidation.

Further to the north-west, a much wider band, extending from Loch Chaorunn to Ant-Aonach, is of fine texture throughout; at Cruach Gille Bheagain, north of Loch Chaorunn, a similar rock loses its massive characters on its margins, where it has been deformed into a closely foliated schist.

Epidiorites associated with Phyllites of Ardrishaig Group (S.W. of Loch Gilp).—The bands to be now considered are more felspathic than those last described and commonly contain porphyritic felspars, as is seen in some of the coarsely crystalline bands that occur to the west of Loch Errol. In the neighbourhood of Ardrishaig and Lochgilphead are many bands that have been deformed into highly fissile chlorite schists, frequently rich in calcite. In these rocks chlorite has been formed at the expense of hornblende, and the latter when present is mainly confined to pale tremolitic types. Epidote, on the other hand, is abundant and often of the pale zoisite type that has been formed at the expense of the felspar. Accordingly, where this epidote occurs, felspar is but feebly represented. Bands of this character are seen on the shore below the Ardrishaig Hotel, and also in a quarry in the vicinity of the Argyll District Asylum at Lochgilphead. In the southern region where metamorphism is more advanced, such chlorite schists are practically absent, possibly owing to the fact that the hornblende, which is darker in colour and often represented by black needles of actinolite, is of a more stable type than the paler and less basic varieties that characterise the Ardrishaig area. Another factor that has probably contributed to the deformation of the finer-textured epidiorites of the Ardrishaig region, is the more yielding nature of the phyllites which enclose them. In the south-eastern area the epidiorites are associated with massive biotite gneisses and quartzose schists that have offered some degree of protection to the sills that are interspersed amongst them, whereas the Ardrishaig Phyllites have been incapable of such effective resistance, and the sills have accordingly encountered the full vigour of the stresses and have often been broken down.

The epidiorites frequently contain grains of blue quartz similar to that which is well known in some types of the Lewisian Gneiss; such grains are, for instance, well seen at the eastern margin of a sill situated half a mile south-west of Fascadale, to the south of Ardrishaig.

A rusty band of hornblende schist, like that described in a previous memoir from the district of Stralachlan,* is seen three-quarters of a mile south-west of Fascadale, along the margin of an epidiorite; it is about 20 yds. wide and extends for about a quarter of a mile. A similar band is seen about half a mile to the

* "The Geology of Cowal," *Mem. Geol. Survey*, 1897, pp. 69, 70.

north of Blarbuy.* All three examples are apparently on approximately the same stratigraphical horizon. They are invariably associated with normal epidiorite, and are therefore probably related to those intrusions, although their aspect in the field somewhat suggests that they may belong to an earlier set. A specimen from the last-named locality, examined by Dr. Hatch, is composed of colourless blades and prisms of tremolite, embedded in a confused felted aggregate of fibres of hornblende and scales of chlorite, together with a little magnetite in dispersed granules. J. B. H.

The epidiorites on the coast between Ellary and the head of Loch Caolisport, and in the adjacent islands, generally behave as sills. The schists in which they occur consist chiefly of phyllites with thin bands of calcareous siliceous schist, but in Cruach nam Lochan and Maoile Fhuar very similar sills are found in beds which contain a considerable proportion of massive quartzite or quartzite schist.

Round lumps of epidosite, as much as 2 ft. long, are common in the sills at Rudha Garbh and on the coast about a quarter of a mile north-east of this place. They have some resemblance to the "pillows" of pillow lavas, but do not seem to contain any vesicles.

The central parts of the broad band on the hilltop about a mile and a half W.N.W. of Achahoish is divided into broad tabular masses by joints inclining gently north-west, which may possibly have been developed during the original cooling of the intrusion. At the highly sheared western edge of the sill, these joints become much steeper, and the intervening tabular masses much thinner.

Great portions of many of the other broad sills are also quite massive, or have not been sufficiently sheared to lose their original lithological structure.

The western edge of the sill a quarter of a mile north-east of Rudha Garbh, contains broad porphyritic felspars, half an inch long, which are slightly cracked, but still show twinning. Other parts of the same sill, however, even where almost free from shearing, show no porphyritic felspars, but numbers of small felspar laths. The boundaries between these two types of rock are sharply defined, even where they are folded, and they are generally nearly parallel to the margins of the sill. It is noteworthy that the porphyritic felspars are sometimes almost free from deformation, even when the matrix is a chlorite schist.† The epidiorite on Eilean Fada also shows the two massive types just described, arranged in thin alternating bands.

Where hornblende occurs, it is usually in the form of small inconspicuous needles; but in the broad bands on the hill a mile and a half west of Achahoish, it is frequently in large crystals, ophitically enclosing felspar. In one type of sheared epidiorite, small augen, usually less than half an inch long, of the ophitic character just described, are distributed at unequal intervals, but with all their long axes parallel, in a dirty green matrix of chlorite schist: it is not certain, however, that the original rock was in all these cases of a

* East of Lochgilphead.

† A similar peculiarity has long been known in the clastic felspar grains in many sheared grits. See, for instance, the description of the Eastern or Moine Schists, in "The Geological Structure of the North-West Highlands of Scotland," *Mem. Geol. Survey*, 1907, p. 620.

uniform character, for some rocks which are but very slightly sheared show a specially large proportion of hornblende about certain centres.

The most sheared types are always very chloritic, and often contain thin parallel seams or rods of ferriferous carbonate, due in part to the liberation of lime during the change from hornblende into chlorite.* Such streaks, sometimes folded, and rods, with their long axes nearly parallel to the dip of the foliation, are well seen rather more than three-quarters of a mile N.N.W. of Rudha Garbh. On the coast a third of a mile west of Rudha Garbh, and on the hill nearly a quarter of a mile south-east of Cruach nam Lochan, the carbonate streaks have not only been folded, but have also been repeatedly crossed by strain-slips.

The sill on the south side of the fault about 1½ mile north-west of Achahoish contains thin seams, sometimes only a quarter of an inch thick, which consist chiefly of felspar, probably an acid plagioclase (11513). These strings are occasionally seen to be involved in small folds, the axial planes of which are parallel to the foliation in them and the rest of the sill.

C. T. C.

Numerous sills of epidiorite occur traversing the schistose sediments south and west of Ellary. The thin bands have suffered considerably from movement, and all original structures have been obliterated. In the thicker bands the rock is massive, and, though augite is represented by hornblende, the original structures of ophitic dolerites are beautifully preserved. The sills in the neighbourhood of Loch Sithein Bhuidhe are about as coarse as the well-known dolerites of late Carboniferous age in the Central Valley of Scotland.

A remarkably coarse intrusion has been well exposed in a road-cutting just west of the Church at Achahoish, at the head of Loch Caolisport: the individual felspars often attain a length of half an inch, and are embedded in plates of hornblende as much as an inch across.

A sill associated with limestone north-east of Lochan na Craige, in the marginal zone separating the phyllitic and quartzitic portions of the Ardrishaig Series, contains little blood-red garnets, and indicates a higher state of metamorphism than most of the rocks round about.

G. W. G.

Epidiorites associated with Erins Quartzite and Ardrishaig Phyllites (*N.E. of Loch Gilp*).—The tract lying to the east of Loch Gilp (Sheet 29) is invaded with epidiorite sills that rival in profusion those occupying corresponding horizons in Knapdale. As already pointed out, however, the bands are narrower, owing to the higher angle of dip. In the eastern part, where they have pierced the quartzite series, they are represented by massive types, corresponding to those between Srondoire and Erins, while garnets are seen in the outcrop to the east of Silvercraigs. Bands of coarse texture occur on either side of Alltoigh, and along the belt extending from Blarbuy, past Dunmore to the coast; in the latter, hornblende

* *Op. cit.* p. 242.

crystals reach half an inch in size. In the vicinity of Blarbuy, pale zoisite enters largely into the composition of the coarse-textured mass, and biotite is seen in one of the bands two-thirds of a mile south-west of that locality. In the western part of this tract these intrusions are largely represented by calcareous chlorite schist, the fissility of which has induced quarrying for building purposes.

Epidiorites associated with the Loch Awe Group. — Very massive types of epidiorite are distributed in the Loch Awe Group, in the quartzite belt between Lochan na h-Inghinn and Loch na Faoilinn. A characteristic feature of these is the development of porphyritic aggregates or lumps, composed of an admixture of hornblende and felspar, which range in size from a quarter to three-quarters of an inch, while occasionally green porphyritic hornblende is disposed in large blade-shaped crystals.

J. B. H.

Coarse, ophitic, pale-coloured epidiorites figure largely to the south between Cruach Lusach and Allt Buidhe. The central outcrop in this belt has a marked columnar structure, which is likely due to the original cooling of the igneous mass. The contact alteration produced by these sills is sometimes very marked, as, for instance, a little to the north of the cairn of Cruach Lusach, and again in a stream course immediately east of the rocky face of Creag nan Iallag. The rocks originally consisted of an alternating set of impure calcareous sediments, and some of the splintery hornfelses produced closely resemble bands of white chert. Dr. Flett describes these altered rocks at the end of this chapter (p. 95).

E. B. B.

Between Eas Daltot and Kilmory Bay, there are two main types of epidiorite sills. One is fine-grained and foliated, and the other much coarser and massive. When they make crags the two can readily be distinguished even at some distance, for the coarse rock breaks off into numerous subangular blocks, while the finer-grained gives rise to a talus composed of large, flat slabs. Good examples of the former are found at the cliff on the roadside south of Castle Sween, and also on the west side of the Cruinn Loch; and of the latter on the east side of this loch, and also on the hillside above Doide Farms.

J. S. G. W.

Of the rest of the area occupied by the Loch Awe Quartzite, namely, a strip along the east coast of Loch Sween, to the north of Eas Daltot, the country lying north of Tayvallich and the Tayvallich peninsula lying to the south of that village, little need be said. The epidiorite sills are numerous, and share fully in the folding of the sedimentary schists. They are sometimes so coarse that their intrusive nature is self-evident, and sometimes, too, they produce notable contact alteration. This latter characteristic is well shown by the prominent sill which is folded into an anticline to the east of the head of the Linne Mhuirich (Barr Mor, Fig. 3). This intrusion is also noteworthy on account of its peculiar composition, as will be seen on reference to Dr. Flett's petrological description (p. 92).

In many cases there is, however, no direct evidence of the intrusive nature of individual bands of epidiorite in this district. At the same time it is improbable that the rocks associated with the quartzite are in any case of contemporaneous origin, for they differ markedly in habit from the vesicular and pillow lavas which are a feature of the black slate and limestone portion of the Loch Awe Group in the Tayvallich peninsula.

The volcanic rocks just referred to above make up a large portion of the Tayvallich peninsula, and reach out to form the Carraig an Daimh and Dubh Sgeir in the Sound of Jura, as well as parts of Corr Eilean and Eilean Mor, off Danna. The description of their field relations has been already given in the preceding chapter, dealing with the Loch Awe Group.

B. N. P.

East of Loch Sween, associated with the black slate and limestone belt of Loch an Add, fine-textured epidiorites occur studded with porphyritic crystals of felspar that are often idiomorphic, and vesicular types are also present. These rocks apparently represent the south-westerly continuation of the main outcrop at Loch Awe, north of the Crinan Canal, where similar porphyritic and vesicular characters are strongly developed. Ash beds have not been detected in this area. The vesicular bands would at first sight suggest that contemporaneous flows were included in the group, but evidence has been obtained that similar rocks to the north are intrusive;* probably they represent injections at shallow depths beneath the crust, although it is possible that lavas may also occur, as Mr. Bailey has described a rock along the same strike with the pillow structure characteristic of the lavas of the Tayvallich peninsula.

Summary.—In summarising the characteristics of the Epidiorite Group it is seen that, firstly, the group shows a diminution in metamorphism from south-east to north-west, in broad correspondence with that of the associated sediments; secondly, that there is a decrease in basicity in a similar direction; thirdly, that the less basic and vesicular types, probably representing shallow intrusions and actual lavas, are restricted to the Loch Awe Group, while the more basic and compact types appear lower down in the sequence. The latter are also the more highly metamorphic, in conformity with the state of alteration of the sedimentary schists with which they are associated.

We are disposed, therefore, to link the metamorphism of these intrusions with that of the sediments which enclose them, and to suggest that such phenomena are connected both with dynamic action and depth temperature; and that the progressive metamorphism broadly corresponds with different depths of the rocks at the period of deformation. In the memoir of the adjacent area in Sheet 37 we have pointed out the upward succession from the Beinn

* See J. B. Hill, "On the Crush-Conglomerates of Argyllshire," *Quart. Journ. Geol. Soc.*, 1901, vol. lvii., pp. 319–320; and "Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, pp. 63–66.

Bheula Series to the Loch Awe Group,* and have shown that the metamorphism diminishes in an ascending direction in the column.†

The abundance of lavas and highly vesicular intrusions associated with the black slates and limestones of the Loch Awe Group in this area strengthens the evidence already presented that this group is the youngest of the schistose subdivisions of the district. In it we find surface or quasi-surface manifestations of pre-folding igneous activity, whereas in the other groups all the epidiorite sheets appear to be normal intrusions.

The hypothesis is further supported by the larger size of the sills, and their greater profusion in a corresponding direction, *i.e.* as the Loch Awe Group is approached. On the horizons of the Loch Tay Limestone and Stonefield Schists they are small and not closely distributed. In the Erins Quartzite they are not only more abundant, but some of the individual intrusions are much larger, while in the higher members, represented by the Ardrishaig Phyllites and Loch Awe Group, they reach a still greater development both as regards size and profusion. Although there is evidently much reduplication due to folding, repetition alone cannot have produced the apparent progressive development of igneous material in the direction named, for the change is accompanied by a corresponding variation in the relative proportions of sedimentary and igneous rocks within the individual groups. The inference, therefore, to be drawn is that at the greater depths the pressure was such that injections between the strata were accomplished with difficulty, while at higher levels they were more readily effected. Still nearer the surface the pressure was so far removed that steam vesicles were abundantly developed, and the intrusions present the general aspect of volcanic rocks, while, finally, in some instances actual lavas were extruded.

J. B. H.

Petrology.

Epidiorites.—In the preceding descriptions three main types of epidiorite have been referred to, namely:—

(1) The volcanic type; associated with the black slates and limestones of the Loch Awe Group.

(2) The north-western intrusive type—often ophitic and conspicuously felspathic; associated with the quartzites of the Loch Awe Group and the phyllites of the Ardrishaig Group.

(3) The south-eastern intrusive type—dark, compact and less felspathic; associated with the Erins Quartzite, Stonefield Schists and Loch Tay Limestone.

All three groups are regarded by Mr. Hill as belonging to a single great suite of igneous rocks. In respect to groups 1 and 2 there is strong petrological evidence to support this interpretation:‡

* "Geology of Mid-Argyll," pp. 59–61.

† *Ibid.* pp. 74–76.

‡ J. S. Flett, in "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909, p. 52.

the uralitic diabases and diabase schists of group 2 have, it is true, more of the normal characters of basic igneous rocks than have the lavas, and are usually less rich in alkali than the latter, but with them are certain aberrant leucocratic types in which alkali felspars are very abundant (keratophyres, soda-felsites etc.), and the whole assemblage is similar to that which accompanies pillow lavas (spilites) in Cornwall and again in the Southern Uplands of Scotland. The petrology of the leucocratic rocks of the Tayvallich peninsula is dealt with in a section following the description of the epidiorites.

(1) The volcanic type (pillow lavas and ash beds).

In the hand specimens the rocks of this series have mostly a dark green colour, from the abundance of chlorite, but in some cases they are pale green or greyish green when chlorite is scanty, and felspar, quartz and carbonates form the bulk of the rock. Some are nearly massive, and, though most of them show foliation, it is exceptional to find them assuming a markedly schistose character. Their most distinctive feature is the presence of steam cavities (Plate V. Fig. 2) infilled with quartz and carbonates; these make white spots on the broken surfaces of the specimens. On weathered faces the amygdales have often been emptied of their contents, and the slaggy character of the rocks becomes very obvious. The cavities are very numerous, and usually not more than a quarter of an inch in diameter, though sometimes much larger than this. Where the rock has been little sheared the amygdales have nearly always a spherical shape; by pressure they become flattened and lenticular, and in the more schistose rocks they are represented by thin streaks which lie parallel to the foliation. The material in the amygdales is usually white or grey; sometimes it is yellow from admixture of ferrous carbonate. It consists of quartz, chlorite and carbonates, and always effervesces readily with dilute cold hydrochloric acid.

Some of these pillow lavas are porphyritic, and contain small idiomorphic white or pinkish crystals of plagioclase felspar. These are never more than one-eighth of an inch in length, and are sometimes broken and torn apart by shearing movements in the matrix. No pseudomorphs after phenocrysts of augite, olivine or other femic minerals, have been observed in these rocks.

Microscopic sections (Plate V. Fig. 3) show that the principal constituents of these pillow lavas are albite, quartz, carbonates and chlorite; of these the albite is the only primary mineral. Iron oxides, pyrites, apatite and sphene or leucoxene occur in all the sections, while epidote and biotite, of secondary origin, are occasionally present. Felspar forms about one-half of the rock, or sometimes rather more than this. Porphyritic structure is much more common than would be suspected from the appearance of the hand specimens. The phenocrysts are always albite, and, though often broken, may have retained their forms exceedingly well, even when the matrix shows a good deal of shearing. Evidently the decomposed, vesicular, fine-grained groundmass has

proved much more plastic under strain than the porphyritic felspars.

In all cases these rocks are very much decomposed and altered: the femic minerals have entirely disappeared even in the least sheared examples. Chlorite has taken the place of original pyroxene, and with it there frequently occur a little quartz and carbonates. Apatite and iron oxides remain, the latter often encircled by secondary leucoxene. It seems reasonable to suppose that rocks so highly vesicular as some of these specimens may have contained originally some glassy base; if so, it is completely devitrified and replaced by secondary products. The groundmass, in fact, consists in all cases of elongated felspars with chlorite, quartz, iron oxides and carbonates. These felspars of the second generation take the form of small laths about four times as long as broad, with indented irregular margins. They sometimes have a parallel arrangement, most pronounced in the schistose rocks, and probably more often due to crushing than to fluxion. Epidote in bright yellow grains is not uncommon, and biotite occurs also in a few of the specimens. The mica has a bright green colour, strong pleochroism and high double refraction. It is a secondary product, as is shown by its occurrence, mixed with quartz and carbonates, in the rounded steam cavities.

When the rocks are powdered and treated with cold dilute hydrochloric acid, all the carbonates are readily and completely dissolved in most cases, showing that they are essentially calcite; but patches of carbonates which effervesce only slowly, and may have a brownish colour, indicate that some dolomite and siderite are also present.

The most striking mineralogical peculiarity of these rocks, which must have been essentially of basic or sub-basic composition, is the abundance of albite both as phenocrysts and in the groundmass. The nature of the felspar is not difficult to determine. The larger crystals show usually Carlsbad, albite and pericline twinning: the smaller are only albite-twinned. The extinction angles of albite twins and of albite-Carlsbad twins in symmetrical sections are those of albite. The optical sign is practically always positive (rarely nearly neutral); sections perpendicular to a negative bisectrix have extinction angles of about 13°. The refractive indices are below those of Canada balsam, and below that of the ordinary ray in quartz, as may often be proved when these two minerals are in contact. A heavy solution, with specific gravity 2·637, separated quite a large amount of pure white felspar out of a typical pillow lava (12453, specimen analysed). This felspar proved to have a refractive index below 1·541, as tested by means of a standardised mixture of clove and cassia oils. The analysis of these rocks shows so little potash that there can only be a small amount of orthoclase. These facts prove that the rocks in question are very rich in albite. Occasionally one meets with crystals in the rock sections which are not pure albite but oligoclase; such, however, are rare, and are usually entirely absent.

A typical pillow lava from the shore $2\frac{2}{3}$ miles south-west of Tayvallich (12453) was analysed, by Mr. E. G. Radley, with the following result (I.):—

	I.	II.	III.	IV.
SiO_2	51·31	49·74	40·55	46·4
TiO_2	1·92	2·05	2·95	0·24
Al_2O_3	12·67	14·85	16·65	20·4
Fe_2O_3	0·54	1·04	1·13	6·9
FeO	7·99	10·61	9·46	
MnO	0·45	0·39	0·20	—
(CoNi) O	trace	nt. fd.	0·07	—
CaO	8·17	6·17	6·06	7·7
MgO	2·19	2·48	5·20	3·5
BaO	nt. fd.	nt. fd.	nt. fd.	—
SrO	nt. fd.	—	nt. fd.	—
Li_2O	(?) trace	(?) trace	(?) trace	—
K_2O	0·54	0·53	0·27	0·54
Na_2O	5·21	4·52	4·76	6·93
H_2O (above 105° C.)	2·31	3·37	3·89	1·1
H_2O (below 105° C.)	0·04	0·05	0·27	
P_2O_5	0·90	0·62	0·73	—
CO_2	6·15	3·18	7·85	5·8
S	—	—	—	—
Fe_7S_8	0·17	—	—	—
FeS_2	0·30	0·13	0·18	—
Cl	—	trace	nt. fd.	—
Total ..	100·86	99·73	100·12	99·51

Analysis II., also by Mr. Radley, gives the composition of an epidiorite from Ardifuir (13040), on the north side of the Crinan Loch ("The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909, p. 55). Analysis III. (E. 4947), by Mr. E. G. Radley, is quoted from the *Geological Survey Memoir* on "The District around Plymouth and Liskeard," 1907, p. 97, and represents a pillow lava of Upper Devonian age, from Devonport Workhouse Quarry, Devonshire. Analysis IV. by Dr. Teall is quoted from the *Memoirs of the Geological Survey*, "Silurian Rocks of Britain," 1899, vol. i. p. 85, to show the composition of the Arenig pillow lavas of the South of Scotland.

The same chemical peculiarities are shown by all these analyses. In the first place the silica is distinctly low, while the alkalies are high, especially when compared with silica. Soda preponderates greatly over potash. The rocks are much decomposed, as is witnessed by the large amounts of combined water and carbonic acid. Lime is not abundant; there is sometimes less than is required to combine with the carbonic acid to form calcite, and never much more; hence the felspars must be nearly entirely albite. The relative abundance of titanium and phosphorus indicates the really basic character of these rocks. Both magnesia and lime are much lower than in typical diabases or basalts.

From Analysis I. the mineral composition of the Tayvallich pillow lava was calculated. It is approximately, albite 44·02, orthoclase 3·18, sphene 2·35, ilmenite 1·82, calcite 11·50, magnesite 1·85, chlorite 15·32, magnetite 0·78, pyrites 0·30, pyrrhotite 0·17, and quartz 19 per cent.

It is evident, then, that among the rocks known as pillow lavas

there is a group which has the well-defined mineralogical and chemical peculiarities indicated above, peculiarities which were first pointed out, it appears, by Dr. Teall in his account of the Arenig lavas of Scotland. To this group the name "spilite" may be given,* as it is already used extensively for types of amygdaloidal diabase,† with pillow structure, and was first used by Brongniart in 1827 in this sense.‡

In the area described in this Memoir the typical spilites and spilite-schists are practically restricted to the Tayvallich peninsula, where they are very numerous; some are found also near the Point of Knap. A few of them are not very vesicular and rather coarse-grained in the matrix; these may very well be thin intrusive sills, which consolidated at no great depth below the surface. The beds regarded by the field geologists as tuffs are invariably much more decomposed, and usually also more schistose than the lavas. They have been weak beds which have yielded readily to folding stresses; in them quartz and carbonates are excessively abundant, while felspar and chlorite are in diminished quantity.

(2) The north-western intrusive type. This group comprises a series of dark green rocks consisting essentially of hornblende and plagioclase felspar. They often form thick sill-like masses, and their intrusive nature can frequently be made out in the field. This is confirmed by the absence of steam cavities in the rocks, and their coarse-grained ophitic structure. Their felspar crystals are often a quarter of an inch in length, and the irregular individuals of uralitised pyroxene which envelop them are in many cases much larger than this (Plate V. Fig. 1). The ophitic structure is very perfect, and may be visible in the hand specimens. These rocks, though uralitised, are typically of massive structure, and must have been less affected by folding movements than the sediments among which they lie. Locally, however, they show a considerable amount of deformation, and pass into green chloritic and hornblendic schists.

In mineral composition, as revealed by the microscope, these rocks present some notable differences from the vesicular lavas previously described. Carbonates are abundant, but less so generally than in the lavas; the chlorite of the latter group is represented principally by hornblende, a mineral which is very rare indeed in the lavas, having been seen in only one microscopic slide of them. Epidote is exceedingly common in the diabases, far more so than in the lavas. The felspar of both series of rocks, however, is principally albite. The abundance of carbonates and chlorite in the lavas goes to prove that these rocks were much decomposed before they were involved in the folding movements. Differences of the same kind are to be observed in Cornwall, where the vesicular spilite lavas of the Middle and Upper Devonian are characterised by abundant chlorite, carbonates and quartz, while the intrusive diabases of the same succession are full of epidote and uralite.

The principal feature of these rocks, in microscopic section

* J. S. Flett, "Geology of the District around Plymouth and Liskeard," *Mem. Geol. Survey*, 1907, p. 95.

† H. Rosenbusch, "Mikroskopische Physiographie," 1908, vol. ii. part 2, p. 1271.

‡ A. Brongniart, "Classification et caractèree minéralogiques des roches," 1827, p. 98.

(Plate V. Fig. 1), is the well-preserved ophitic structure. Large masses of hornblende, enclosing rectangular sections of plagioclase felspar, are visible in the slides. The hornblende is mostly of the watery green colour which is frequent in the uralite of diabases; for the most part it is compact, and polarises uniformly over considerable areas, but at the edges it becomes jagged and indented, and may be surrounded by bundles of needles which shoot out into the felspar. The pleochroism is not strong, but there are pleochroic halos around epidote inclusions; brown hornblende, which might be primary, has not been observed in the slides. In the Kilmartin district * some of the diabases contain remains of original augite, but this mineral has not been met with in rocks of this type in Sheet 28.

In addition to hornblende, and usually in close association with it, there is often a limited quantity of biotite and chlorite. The mica has a clear brown colour with marked dichroism, and from its mode of occurrence it must be secondary, though often rather well crystallised. In Eilean Traighe, a mile west of Tayvallich, there is a coarse diabase (11171, 11885) with very perfect ophitic structure, but all the augite has been replaced by chlorite and yellow brown biotite, in scaly aggregates containing long pointed prisms of actinolite. This rock is exceptionally rich in large apatites, the central parts of which are rendered turbid by innumerable fluid enclosures (Plate V. Fig. 1). The chlorite is sap-green, gives grey and blue polarisation colours, and has often well-developed polysynthetic twinning.

Sphene is exceedingly abundant, in large networks composed of small irregular grains, and evidently formed after primary titaniferous iron oxides. In some rocks these aggregates have so perfectly the original shapes of ilmenite growths in recent dolerites that it is evident the rocks have suffered very little from shearing. Epidote also is a very frequent mineral. Its colour is bright yellow, and it occurs both in large crystals which have fairly well-defined crystalline form and in grains of all sizes, down to minute specks enclosed in the hornblende. It is often accompanied by chlorite, but its principal habitat is the felspar, which is often quite filled with minute grains of this mineral. We can hardly be in error in inferring that much of the epidote has arisen from the lime-felspar molecule in the original plagioclase. Except for inclusions of fibrous hornblende, granular epidote and fluid cavities, the felspar is water-clear. It shows polysynthetic twinning of the usual types, and has the extinctions and refractive index of albite. Large crystals of apatite, bent and broken, are a feature of some of the slides. Carbonates occur, sometimes in large quantity, and there is often a little quartz, none of which can be proved to be primary.

The examination of a series of these rocks leads us to the conclusion that they were originally ophitic dolerites, which may or may not have contained olivine. Their felspar was probably one of the lime-soda series, and not so rich in alkalies as that of the pillow lavas. This is rendered probable, not only by the abundance of epidote in them, for the formation of albite and epidote from labradorite, etc., by metamorphism is too well known to excite comment,

* "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909, pp. 50, 52.

but also by what we know of the bulk composition of these rocks. No analyses of those which occur in this Sheet have been made, but the analysis of a rock of this type from the Crinan Loch, in Sheet 36, given in the Survey Memoir on that Sheet (p. 55), shows that they contain less alkalies than the pillow lavas, though more than ordinary diabases.

A furlong south-south-west of Sithean Reidh, $2\frac{1}{4}$ miles north-east of the Point of Knap, Mr. Grabham obtained pale veins of coarse albite pegmatite (11370) in some of these epidiorites. This pale grey rock consists of albite, with a little ophitic uralite, epidote and sphene. Some of the albite has checker structure, and may be secondary after orthoclase.

Before proceeding to the consideration of the next group of epidiorites in this region, we may mention the frequent occurrence of epidosites in connection with the pillow lavas and the diabases of the same series near Tayvallich. These epidotized rocks form cores to the pillows, often with a hollow space in their interior, or occur as irregular segregations. In some of them the original structures of the igneous rocks are in great measure preserved. Hence it is possible to say that some epidosites were produced from vesicular porphyritic pillow lavas, and others from coarse-grained ophitic diabases. A molecular replacement of the original minerals of the rock by epidote and quartz has taken place; in other words, the process is a metasomatic one. The ultimate product is a granular mixture of quartz and epidote; in the intermediate stages there are remains of the original minerals. Epidotization of pillow lavas is by no means uncommon, and it is well seen at Mullion Island and Port Isaac, in Cornwall, and in Anglesey.

Replacement by epidote first affects the felspars, so that in the vesicular types there are long narrow pseudomorphs of epidote after felspar (13218), before the structure of the groundmass is essentially modified. In the ophitic diabases the felspar may be completely epidotized when the uralitic amphibole still remains and shows its ophitic outlines. Thereafter the groundmass of the lavas becomes a granular mixture of small yellow epidotes and transparent quartz. In the ophitic rocks the hornblende seems to waste away by passing into bundles of tapering fibres embedded in quartz (11870). Clusters of radiate green chlorite and yellow brown biotite also make their appearance, a fact which suggests that the changes described previously in the hornblende of the Eilean Traighe diabase may be a stage in the process of epidotization. The ilmenite or titaniferous iron oxide is often surrounded by borders of leucoxene, but may be fairly well preserved in the epidosites; while the large prismatic apatites of the diabases apparently resist the solutions which effected the replacement, as they are beautifully perfect in some of the most altered rocks (13242). In the vesicular spilites (Plate V. Fig. 2), the steam cavities are occupied by quartz, epidote and carbonates, but the latter occur only in small amount, and seem rather to be dissolved away than to be deposited during the period of metasomatism. The epidotized pillow lavas have well-rounded amygdales; in some cases also they are very irregular, as in recent pumiceous rocks. They show exceedingly little flattening or elongation by pressure, consequently

it seems likely that epidotization took place before the rocks were deformed, and the epidotized portions (13218) of the lavas were more rigid and less easily sheared than the other parts.

(3) The south-eastern intrusive type. Very few specimens of the rocks of this group have been collected and sliced, so that the materials are not available for a detailed petrographical description of them. They have, however, certain features which distinguish them clearly from all the epidiorites that occur in the country to the north-west of Loch Caolisport. One of these features is the constant presence of small, pale pink, idiomorphic garnets. Their hornblende is better crystallised and of a darker green colour than in the epidiorites of group 2, and most of these rocks show no traces of ophitic structure, though obscure remains of it may be occasionally detected (13337). Although none of these rocks is a perfectly typical hornblende schist, with parallel orientation of its constituents, and both in hand specimens and in the field they have often a rather massive appearance, there can be no doubt that they represent a more highly metamorphic condition of basic igneous rocks than the epidiorites which lie to the north-west of them. The minerals of these rocks are garnet, dark green hornblende, felspar (often albite), quartz (sparingly), apatite and iron oxides. Brown biotite is rather common, and granular epidote or zoisite is often very abundant in the felspars, which latter form a water-clear, recrystallised mosaic with quartz. Many of the larger crystals of hornblende contain small enclosures of quartz in such numbers as to give them a sieve-like appearance.

Leucocratic Intrusions.—At Barr Mor, on the east side of the upper end of Linne Mhuirich (Fig. 3), a fine-grained intrusive igneous rock (11170) which presents peculiar characters was mapped by Dr. Peach. This rock has a rather dark brown colour in the hand specimen, and is full of small glancing scales of biotite, which have a parallel arrangement: in consequence of this it has a distinct fissility. Small phenocrysts of brownish-red felspar with fresh bright cleavage faces are scattered through the matrix, but are by no means conspicuous. The microscope shows that this rock consists very largely of albite with greenish biotite, iron oxides, epidote, apatite and a little muscovite and quartz. There is no hornblende or pyroxene.

The small phenocrysts are only felspar, and are highly idiomorphic, though sometimes bent and broken by shearing. The felspars of the groundmass are lath-shaped, elongated and sub-rectangular in outline, but their edges are serrate, so that they interlock to a small extent with one another. A distinct, though not highly perfect, parallel arrangement is a feature of this groundmass. Seeing that the phenocrysts are so little crushed, this structure is probably due to original fluxion, though it may have been accentuated by pressure acting at a later period on the solid rock. The twinning of the felspar is nearly always polysynthetic, on albite and Carlsbad plans. All the felspar has refractive indices below those of the Canada balsam in which the slides are mounted, and below those of quartz where these two minerals are in contact. It has angles of sym-

metrical extinction up to 12°, and the difference between the extinctions of albite and Carlsbad twins amount in all cases to only a few degrees. Sections perpendicular to an axis are negative. In a solution with specific gravity 2·637, a fair amount of pure felspar floated; at 2·674 a larger amount was obtained, but this portion was full of small enclosures of magnetite, biotite etc. These observations prove that the rock is rich in oligoclase-albite and albite. Probably also it contains a small amount of orthoclase, but this was not identified with certainty.

A very small quantity of quartz may be found in the slides, usually in little patches of rounded grains mingled with perfectly clear albite, which can best be distinguished from it by the use of convergent light. These quartz-albite aggregates may be secondary or produced during the metamorphism of the rocks. The biotite has strong pleochroism from pale yellow to blackish brown, occasionally green. It is in small crystals, which lie between the felspars and are not to any extent eumorphic; they are usually fresh, and are probably for the most part primary. The muscovite, on the other hand, is secondary, as it occurs mainly where lines and bands of crushing traverse the rock. Iron oxides are common, principally magnetite in very small octahedra. Pyrites, apatite and zircon are also present, and a few crystals of carbonates.

In the abundance of alkali felspars, the porphyritic structure, and the somewhat orthophyric character of the groundmass, this rock has some resemblance to the bostonites, from which, however, it differs in the conspicuously polysynthetic structure of the felspars and the abundance of albite. These latter features connect it with the keratophyres, with which also it shares the abundance and frequently green colour of the biotite. A rock practically identical with this one occurs about 2 miles to the north, at Cnoc na Faire in Sheet 36, and has been described in the Memoir on that Sheet (p. 53). It may be noted also that keratophyric rocks, according to Rosenbusch,* are among those described by Cowper Reed † from the vicinity of Fishguard, where spilites occur, and that a keratophyre occurs at Gorran Haven, in Cornwall, one of the English localities for pillow lavas.‡

A different type has been obtained a little east of the north end of Linne Mhuirich, from an exposure considered by Dr. Peach to belong to the same intrusion. It contains large grains of quartz, bluish grey and visible in the hand specimens, together with much quartz in the matrix. This rock (11292–4, 11299) shows no ophitic structure, and was certainly not a diabase of the same type as the normal epidiorites of the region. It is rich in albite and biotite, and contains hornblende, though not in great quantity; this hornblende forms long prisms, and has an unusually dark green colour with rich pleochroism. Epidote is very common in small granules, and in one slide of this rock the larger epidotes sometimes contain centres of brown, intensely pleochroic orthite (13243).

* H. Rosenbusch, "Mikroskopische Physiographie," 1908, Edit. 4, Band ii. Hft. 2, p. 1274.

† F. R. Cowper Reed, "The Geology of the Country around Fishguard, Pembrokeshire," *Quart. Journ. Geol. Soc.*, 1895, vol. li. p. 169.

‡ "The Geology of Mevagissey," *Mem. Geol. Survey*, 1907, p. 56.

We pass next to the description of the pink intrusive porphyry (Chapter VII.), which penetrates rocks of the pillow lava group in the shore section about a mile north of Rudha Riabhag. It varies somewhat in character, but has mostly a dark reddish brown colour and a fine-grained matrix with large pink felspar phenocrysts. In many specimens there is little foliation to be detected by the unaided eye, though the microscope usually shows that there has been a certain amount of crushing. The porphyritic felspars are sometimes orthoclase, Carlsbad twinned; in most cases, however, they show albite veining, and consist of a rather coarse-grained microperthite. Very characteristic of this rock is the great abundance of large crystals of alkali felspar, which show a complicated pattern of little squarish or rectangular twin patches, building up an aggregate recalling the rectangular lattice-work of some kinds of microcline. This felspar is albite, and has been described by Professor Becke * as checker-board albite, from its resemblance, when half the twin plates are in a position of extinction, to a draught-board with black and white squares (Plate V. Fig. 4). He believes it is secondary, and due to replacement of orthoclase by albite. There is no proof of this in the slides of this porphyry, but it may quite well be the case. Sometimes one-half of a Carlsbad twin is checker-albite (11165), the other half microperthite; in other cases the checker-albite forms broader or narrower patches in a matrix of orthoclase, making a coarse and abnormal microperthite. Many crystals are entirely checker-albite, and on their edges, as Becke describes, there may be a border of small albites with broader and simpler twinning. There are no phenocrysts of albite such as occur in the pillow lavas, and no soda-lime felspars. It is doubtful whether porphyritic quartz occurred in the rock; if so, its crystals were scarce, and are now reduced to granulitic augen. The large felspars are often nearly quite idiomorphic, and, though broken, are seldom rounded or lenticular. Porphyritic quartz, however, often proves more brittle than felspar under strain.

Biotite, with pleochroism from yellow to brown, occurs in small scales in the groundmass. Some of it may be primary, as in the Barr Mor rock, but often it has arisen from introduction of basic material from the adjacent pillow lavas. In one slide there are pseudomorphs of yellow epidote showing the typical outlines of pyroxene (13221). Ferro-magnesian minerals must, however, have been exceedingly scanty in the original rock.

The groundmass consists of orthoclase, albite and quartz, with biotite and muscovite. The felspar often occurs as broadish irregular laths; albite and quartz may form nests or small patches of rounded grains. The amount of quartz is really very small; it is principally seen in veins or threads, where the rocks have been crushed, or in small clusters behind the phenocrysts of felspar, where the groundmass has sheared around them. Much of it may be secondary, and produced with muscovite after potash felspar. The white mica is found principally in small scales in the matrix, where that shows evidence of crushing. Epidote is often very abundant, both in small disseminated grains and in clusters

* F. Becke, "Zur Physiographie der Gemengteile der krystallinen Schiefer," *Denks. Kaiser. Akad. Wien.*, vol. lxxv. 1906, p. 28.

forming pseudomorphs after augite. In the centre of the larger crystals there are sometimes dark cores of orthite. Apatite, zircon, iron oxides and pyrites are the principal additional minerals.

This rock is evidently a porphyry. It has the typical structure of the members of this group, and is clearly intrusive. If the quartz of the groundmass is entirely secondary, the rock is a syenite porphyry, and the great abundance of alkali felspar and frequently orthophyric structure of the groundmass favour this supposition. If the quartz is in any considerable degree primary, it is more reasonable to call the rock a granite porphyry or pyroxene-quartz porphyry. Its most interesting features are the great abundance of alkali felspar, and the scarcity of femic minerals and quartz. Shearing has affected the groundmass rather than the phenocrysts, which are often remarkably perfect. When the matrix becomes schistose, much white mica develops in it (11163).

An analysis of the pink porphyry (13221) which is exposed in the shore section at high-water mark, half a mile south-south-west of Rudha na h-Airde (fully 4 miles south-south-west of Tayvallich), has been prepared in the Survey's laboratory by Mr. E. G. Radley, and is given below (I.):—

	I.	II.
SiO_2	72·51	65·67
TiO_2	0·31	0·19
Al_2O_3	13·10	13·72
Fe_2O_3	2·81	0·50
FeO	0·90	1·17
MnO	0·20	0·13
(CoNi)O	nt. fd.	0·02
CaO	1·84	3·21
MgO	0·20	1·52
K_2O	0·33	1·68
Na_2O	6·76	6·26
Li_2O	nt. fd.	tr.
H_2O (at 105° C.)	0·04	0·28
H_2O (above 105° C.)	0·35	0·84
P_2O_5	0·06	0·09
FeS_2	nt. fd.	0·03
CO_2	0·76	4·86
	100·17	100·17

The high percentage of silica indicates that this rock is of distinctly acid character, a granite porphyry rather than a syenite porphyry, and part of the quartz it contains must be original. The most interesting feature of the analysis is the great predominance of soda over potash and lime, which explains the abundance of albite seen in the microscopic slides. The rock, in fact, belongs to the soda-felsites or soda-granites, showing even in a more extreme manner than the spilites the characters of the magma. There can be little doubt that it, as well as the keratophyres previously described, is "consanguineous" with the pillow lavas; and, as confirmation of this, we quote the analysis of another granite porphyry (or syenite porphyry) which accompanies the spilites of Veryan age (Arenig?) at Porthallow, in the Lizard district of Cornwall (II., also by Mr. E. G. Radley). The latter rock contains about 6 per cent. of carbonate

of lime, and, if we allow for this, we find that in it, too, the principal constituent must be soda-felspar.

Very interesting phenomena are shown at the margin of the porphyry, where it is in contact with the pillow lavas. Much movement has gone on at these junctions, and the rocks are distinctly schistose. There has been also some blending and intermixture during shearing. The pillow lava is still recognisable by its amygdales and the large plates of ilmenite, changing to leucoxene; the porphyry contains very perfect and unbroken phenocrysts of alkali felspar. In both rocks, however, there is abundance of fine green biotite. The chlorite of the pillow lava and the alkalies of the porphyry have reacted on one another to form biotite; alkalies have been transferred to the basic rock, and magnesia to the acid one. The zone of interaction is a narrow one (13219).

The blocks of pink porphyry in the "porphyry breccia" exposed in the shore section north of Rudha Riabhag present all the essential features of the porphyry described above, and are practically identical with it in character and composition (11164, 11873, 11888, 13214, 13222). They contain even the pseudomorphs after porphyritic augite. The matrix is often very rich in green biotite, and highly schistose, like the sheared junctions of intrusive porphyrite and pillow lava. The finer-grained portions of this bed are full of small crushed checker-albites and microperthites, with a sheared matrix that is rich in calcite, green biotite, epidote and muscovite.

Hornfelses of Creag nan Iallag.—In a section exposed in the burn immediately east of Creag nan Iallag, Mr. Bailey obtained a series of peculiar rocks (p. 82) which may be described as adinoles and calc-silicate hornstones. They are part of the Loch Awe Group, and are in contact with a large sill of epidiorite, so that there is no difficulty in explaining their exceptional features as due to contact action. In the hand specimens some of these rocks are grey, others are cream-coloured, and so fine-grained that they have a close resemblance to cherts. When tested with a pocket-knife they prove as hard as steel, but before the blowpipe they fuse rather easily in thin splinters, and colour the flame yellow. In microscopic section (12401), they are exceedingly fine-grained, but it can be made out that the cherty-looking matrix consists of quartz and alkali felspar; these minerals can best be distinguished through their refractive indices as compared with one another and with Canada balsam: they have no characteristic shapes, and are not large enough to be tested with convergent light, except in a few small veins, where a coarser-grained mixture of quartz and albite can be identified with some difficulty. In this matrix there lie enormous numbers of minute grains of epidote (Plate V. Fig. 6), which, in contrast to the quartz and felspar, often show rudimentary crystalline form. They are usually turbid at their centres, with small dusty enclosures. A few acicular prisms of green amphibole are also visible in the slides, and many dark clusters of granules with very high refraction—presumably sphene.

Small oval or irregular spots, about one-sixteenth of an inch in diameter, are visible in the hand specimens. They may be zoned, and do not differ from the rest of the rock, except that the pale

zones are rich in quartz and felspar, while the darker, greenish yellow bands are full of epidote and sphene.

These rocks are clearly adinoles, and the excellent preservation of the original spotting shows that they are very little sheared. The movements which have recrystallised the other sediments and converted them into schists have been insufficient to modify them. This is an instance of the power of fine-grained hornfelses to resist regional movements, a property which is exemplified in several parts of the Highlands, especially in the contact aureole of the Carn Chuinneag augen gneiss in Ross-shire.*

With these fine adinoles there are tough dark green or greyish green rocks, very rich in actinolite, in fibres or prisms, and also containing some quartz, felspar, calcite, epidote and sphene. These rocks are in places hardly at all schistose, and their amphibole forms stellate to radiate groups, in the centre of which there is often a patch of carbonates (12403-5). In these cases the original material has contained more iron and magnesia (probably as siderite and dolomite), and green hornblende has in consequence been produced in considerable amount. J. S. F.

EXPLANATION OF PLATE V.

PHOTOMICROGRAPHS OF ROCKS.

FIG. 1.—*Epidiorite* (11171), Eilean Traighe (magnified 8 diameters, ordinary light). There are large rectangular sections of plagioclase felspar (albite), very clear and transparent, embedded in a matrix which consists of scaly biotite and chlorite, mixed with some granular epidote. This matrix represents original augite, and the ophitic structure of the rock is sufficiently clear. Many hexagonal cross-sections of apatite are visible in the dark chloritic interstitial substance, and these are often rendered turbid at their centres by numerous inclusions. Thin black plates of ilmenite appear in several parts of the field.

FIG. 2.—*Pillow Lava, or Vesicular Type of Epidiorite* (13218), $\frac{5}{8}$ of a mile north of summit of An Aird, and $2\frac{1}{4}$ miles south-west of Tayvallich (magnified 14·5 diameters, ordinary light). A large, irregular steam cavity is seen, filled with epidote, quartz, chlorite and carbonates. The rock has a dark groundmass with small lath-shaped felspars; although these are to a large extent replaced by epidote, the igneous structures are well preserved.

FIG. 3.—*Pillow Lava or Spilite* (12453), $\frac{5}{16}$ of a mile north of summit of An Aird, and $2\frac{3}{8}$ miles south-west of Tayvallich (magnified 29 diameters, crossed nicols). The photograph shows that the rock is non-porphyritic, and not very vesicular. It consists of albite in narrow prisms, with irregular grains of calcite and a certain amount of chlorite between. This is the rock of which an analysis was made by Mr. Radley (see p. 87).

FIG. 4.—*Nordmarkite* (11881), pebble in "boulder bed," south side of road, Rudha na Cille, between Keillmore and Keillbeg (magnified 35 diameters, crossed nicols). The rock is coarse-grained, and consists of large irregular crystals of alkali felspar; one of these shows the characteristic structure of checker-albite. With the felspars there is a little quartz, not visible in the photograph.

FIG. 5.—*Crinanite* (14174), North-West dyke which forms Stac nan Sgarbh, 1 mile north of Inver Cottage (Sheet 27), Jura (magnified 25 diameters, ordinary light). There are large grains of olivine, which have cracks lined with serpentine, and lath-shaped plagioclase felspars embedded in ophitic plates of augite. Cloudy patches of radiate zeolites occupy steam cavities, and fill the interstices between the felspars. This rock has been analysed (see p. 118).

FIG. 6.—*Spotted Adinole or fine Calc-Silicate Hornfels* (12400), 770 yds. west-north-west of Cruach Lusach (magnified 11 diameters, ordinary light). In a colourless matrix of quartz and alkali felspar there are innumerable granules of dark epidote and sphene. Small rounded pale-coloured spots are scattered through the rock (see p. 95).

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* *Sum. Prog. Geol. Survey* for 1901 (1902), p. 108.

Fig. 1.

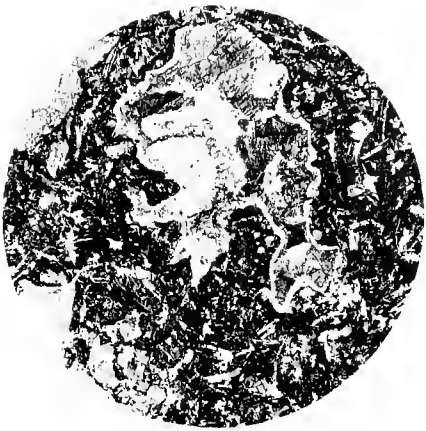

Fig. 2.

Fig. 3.

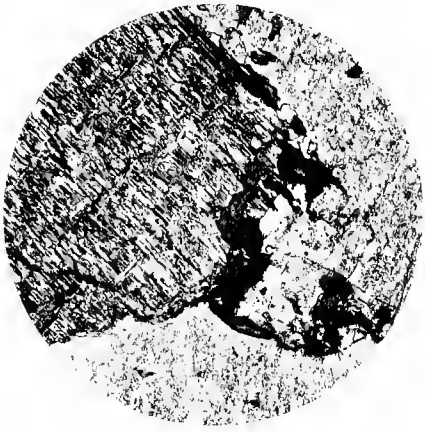

Fig. 4.

Fig. 5.

Fig. 6.

PHOTOMICROGRAPHS.

CHAPTER IX.

THE METAMORPHIC ROCKS OF JURA.

Jura was mapped for the Geological Survey by Mr. S. B. Wilkinson, assisted by Dr. B. N. Peach, who undertook a small area in the north-west corner. Mr. Wilkinson retired from the Scottish branch of the Survey in 1908, but left a series of notes describing the geology of the island. These have been supplemented during a recent visit, and the results, so far as the metamorphic rocks are concerned, have been embodied in the following account.

The correlation of the various subdivisions of the schists of Jura with those of the mainland of Argyll is fraught with grave uncertainty. It is generally assumed, however, that the quartzite, which is the predominant member in the Jura sequence, corresponds to the quartzite of the Loch Awe Group. The two have much in common, being in large measure pebbly and of similar type, while they are, in each case, intimately associated with black slates and limestones, both pebbly and non-pebbly. Dr. Flett has examined a number of slides of the quartzite of Jura, and finds that the felspar pebbles are microcline and perthitic orthoclase; in the Loch Awe Quartzites of the mainland the same felspars occur with a small amount of oligoclase or albite.

No evidence has been obtained in Jura itself bearing upon the question of the original order of succession of the schists. Even in the case of Islay, to the south, and Scarba, to the north, where such evidence has been claimed, there is only partial agreement as to how it should be interpreted. Under these circumstances it will suffice to point out, in the sequel, the relationship which exists between Jura and its two neighbours, and to refer the reader to the descriptions which have already appeared dealing with the geology of the latter.*

The schists of Jura strike very persistently parallel to the length of the island, and dip south-east at angles averaging about 30°. In the north-east corner of the island, however, the strike swings round into the north and south direction, characteristic of the east coast of Scarba, while at the other extremity there are still greater irregularities of structure, continuing the complication of Islay, across the Sound.

Two main divisions may be recognised in traversing the island from west to east.

1. Jura Quartzite, interbedded with the Scarba Black Slates towards its eastern margin.

* B. N. Peach and S. B. Wilkinson, "The Geology of Islay," *Mem. Geol. Survey*, 1907. B. N. Peach, "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909.

2. Port Ellen Phyllites, named from their type locality in Islay. With this group there are numerous porphyritic epidiorite sills.

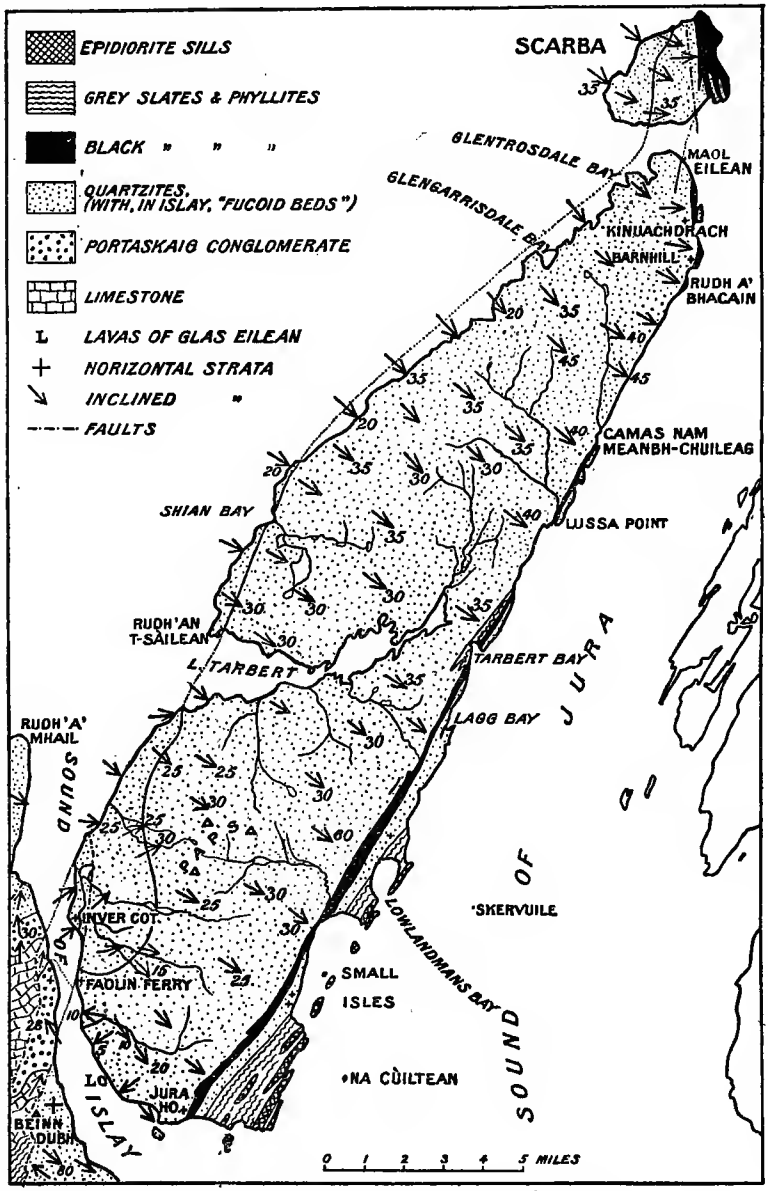

FIG. 5.—Sketch Map of Jura (dykes omitted). The eastern margin of the vitreous quartzite (massive quartzite of Scarba) is shown.

The epidiorite dykes of the island may also be mentioned here. Their mode of occurrence, as vertical dykes, shows pretty clearly that they are of later date than the main folding, so that they

obviously can have very little connection with the sills associated with the Port Ellen Phyllites.

I.—The Jura Quartzite.

(a) *The Jura Quartzite West of the Main Black Slate Band.*—Along the shores of the Sound of Islay, in the vicinity of Inver Cottage, there are excellent exposures of a thick, white, well-bedded, fine-grained, vitreous quartzite, which dips north-east at angles of about 25°. The coast section is oblique to the strike of the beds, but for a distance of a mile scarcely a single layer of pebbles can be detected in the rock.

This outcrop of fine-grained vitreous quartzite is unique in Jura, although it is the prevalent type in North Islay, as, for instance, at Rudh' a' Mhail. To the east for some distance it is bounded by a shatter belt, which determines the straight run of the coast between Faolin Ferry and Inver Cottage. Evidently this shatter belt marks the continuation of the powerful Beinn Dubh fault of Islay.

The quartzites to the east of this fault at Faolin Ferry are non-vitreous, and also contain pebble bands, so that they are not of the Inver type at all. They correspond, rather, with the quartzites extensively developed east of the Beinn Dubh fault in Islay opposite.

On the shore a mile north of Inver Cottage the fine-grained quartzite dips beneath a quartzite containing pebbly layers, but otherwise of exactly the same fine-grained vitreous type. The pebbles are, for the most part, rather large grains of quartz, which are often blue. They are generally disposed in definite seams, either parallel to the main bedding planes or oblique, in which case they furnish very pretty examples of current-bedding. Vitreous pebbly quartzites of this type dip off the fine-grained type near Loch Gruinart in Islay (Sheet 27), but are otherwise unknown in the north end of the sister isle.

The coast-line to the north is determined by a second line of smash, and it seems safe to assume that this marks the continuation of another of the faults which have been mapped in Islay on the other side of the Sound. Probably this and the neighbouring Faolin Ferry fault unite on the shores of the bay a little to the north-east, for there is a wide belt of shattered rock here, while the sections to the east seem intact.

To the east of this belt of broken rock the coast-line follows the strike of the beds, and the exposures all belong to the vitreous type of quartzite with occasional pebbly layers. On turning round the corner into Loch Tarbert, however, these quartzites dip beneath others, which, while they are still pebbly and false-bedded, no longer possess a vitreous fracture.

The same experience is encountered to the north of Loch Tarbert, for the vitreous quartzites, with pebbly layers, catch on to the projecting coast-line between Rudh' an t-Sàilean and Shian Bay and dip south-east under non-vitreous quartzites.

Beyond Shian Bay the eastern margin of the vitreous quartzite

is hidden beneath the sea for several miles, but it has been traced by Dr. Peach * through Scarba and Lunga to the north.

Returning now to the south side of Loch Tarbert, it is clear from the inland dips recorded by Mr. Wilkinson that the outcrop of the pebbly vitreous quartzite must be of the general shape indicated upon the sketch map. It is clear, too, that the non-vitreous quartzites already mentioned at Faolin Ferry occupy a position equivalent to that of the non-vitreous quartzites of Loch Tarbert.

The belt of quartzite which intervenes between the vitreous or massive zone, to the west, and the black slate band, to the east, is remarkable for its variations in character from south to north.

In the south it is precisely similar to its continuation upon the opposite shores of the Sound, east of the Beinn Dubh fault. The section between Faolin Ferry and Jura House is monotonous in the extreme, being composed of false-bedded, more or less pebbly quartzites. Some of the beds are pebbly throughout, and a few are coarsely so. More often it happens that the pebbles are restricted to thin seams or bands. Only one flaggy exposure was noticed in the traverse of this coast section.

In the middle of the island, along the shores of Loch Tarbert, new types of rock appear, cleaved grey sandy shales or mudstones and flaggy beds being intercalated among the quartzites. The latter in other respects retain their old characters, and, since the flaggy beds are very sparsely distributed, the section does not differ much from that of the south coast.

Northward, however, the cleaved flaggy shales play a much more prominent rôle. Thus in the coast section from Glengarrisdale Bay, through the Gulf of Corryvreckan to a little south of the Maol Eilean, there is scarcely a cliff where the quartzite is not interrupted by a flaggy intercalation. Some of these beds are crowded with "worm casts," first recognised by Dr. Peach. Such are specially well seen on either side of Glentrosdale Bay. The same observer draws attention to the occurrence of syenite pebbles, recalling those of the Portaskaig conglomerate, embedded in a quartzite bed of this series at the headland west of Glengarrisdale Bay.

It has been mentioned above that the flaggy intercalations form a persistent feature of the quartzite right through the Gulf of Corryvreckan as far as the Maol Eilean. A little south of this, in the coast section, they cease, leaving a distinct zone, half a mile across, distinguished by the absence of flaggy bands of any sort. This brings the classification of the north Jura schists into close accord with that established by Dr. Peach in Scarba. Three of the zones in the quartzite of the latter island clearly cross over into Jura, namely, the "massive" or "vitreous quartzite," the "flaggy quartzite" and the "pebbly quartzite" followed by black slates.†

* This is the margin between the "massive" and "flaggy" zones of Scarba, cf. *Sum. Prog. Geol. Survey* for 1902 (1903), p. 73.

† These three zones are 3, 2 and 1 of Dr. Peach's list on p. 28, "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909.

While the "pebbly quartzite" of Scarba can be recognised in north Jura, and occurs for the most part in rather massive beds, it is not strikingly pebbly, and shows no conglomeratic tendency like that so marked in Scarba. It is characterised at more than one point by thin seams or films of black slate, which make their appearance almost as soon as the flaggy intercalations fail in the group to the west.

(b) *The Main Black Slate Band and the Quartzite East of it, to the Port Ellen Phyllites.*—The main black slate or phyllite band referred to in the heading enters the island near Jura House, in the extreme south, and finally leaves it again beyond Kinuachdrach, in the extreme north. In the interval it clings closely to the eastern coast, and not infrequently passes beneath the waters of the Sound of Jura. It appears to correspond with a black slate band mapped at Port Ellen in Islay (Sheet 19), while its northern continuation across Corryvreckan is undoubtedly to be found among the black slates of Scarba.

The Jura black slate comes into direct contact with quartzite to the west only at the northern extremity of the island.

Elsewhere the two are separated by grey slates or phyllites, which, however, except at Tarbert, are of quite subordinate importance.

It is also only at the north end of the island that the black slates are accompanied by limestone; the latter occurs in thin beds, as it does in Scarba, and is dark grey in colour and either pebbly or non-pebbly, just as is the case in the Loch Awe Group of the mainland.

The black slate band is followed to the east by quartzites which are often of a dark grey or black hue, frequently coarsely pebbly and very rarely conglomeratic. These quartzites everywhere carry intercalations of black slate which, so far as can be judged from the limited exposures, increase in importance to the north as Scarba is approached.

The local variations of the group, now under consideration, are sufficient to warrant a brief description of a few of the main exposures from south to north along the line of outcrop.

In the coast section below Jura House the black slates, or phyllites, are very well exposed. They are much veined with quartz and have been greatly crumpled. They are separated from the quartzite to the west by a thin set of grey phyllites, in part sandy, and are followed to the east by dark pebbly quartzites, including a band of black slate which has determined the site of a small stream gorge dissecting the cliff. The remainder of this southern coast-line west of the Port Ellen Phyllites is tiresome to traverse and of little geological interest.

The section to the north, along the shore of the Bay of Small Isles, is much more easily visited. The black slates are excellently exposed at the head of the bay. They have suffered greatly from movement, their early cleavage planes being twisted and crumpled and crossed by a second set of planes of the obvious strain-slip

type. Before reaching the quartzite to the east they become mixed with pelitic intercalations and pass into a thin intermediate group of grey sandy phyllites.

The quartzites, lying between the black slates and the Port Ellen Phyllites, occupy the coast-line in front of the Small Isles Village. They are mostly black gritty quartzites with occasional partings of black slate.

The group is readily followed northwards to Lagg Bay, still preserving its general characters unaltered. By the roadside near Gate House, a mile south of Lagg, there are fine exposures of very pebbly quartzite with pebbles, as large as pigeon eggs, consisting chiefly of quartz and felspar. These conglomeratic pebbly quartzites lie a little to the east of the main black slate band, and their continuation northward makes the headland east of Lagg Bay. The shores of this bay and coast-line to the north afford a most interesting section. The main black slate band, which serves as datum line in eastern Jura, comes out to sea a little south of the entrance to Tarbert Bay. It is here separated from the western quartzite by an altogether exceptional spread of soft grey and flaggy slates. To the east it marches with a set of coarse pebbly grits, quartzose beds and quartzites, interbedded with dark grey and black slates, some of which are as pebbly as the quartzites themselves. A few of the beds of this mixed series, about 500 yds. south of where the main black slate outcrop reaches the shore, are actually conglomeratic and contain fragments of grit and black slate.

The northern shores of Tarbert Bay consist of the same grey slates that intervene on the southern shores between the main black slate band and the western quartzite. They reappear in the coast section once again a couple of miles further north, but are evidently diminishing in importance in this direction.

The main black slate band outcrops at the entrance to Tarbert Bay and has been somewhat extensively wrought in the past, but now the quarries are entirely abandoned.

The exposure of the mixed series of quartzites and black slates, which doubtless follow to the east of the main slate band, is here limited to a very narrow coastal strip.

An interval follows to the north, in which the group is lost to sight beneath the waters of the Sound of Jura. The black slate band, however, comes ashore once again and gives rise to Lussa Bay, behind Lussa Point, the latter consisting of the pebbly eastern quartzite. The black slates, which have been wrought years ago at Lussa Bay, form a narrow outcrop for a couple of miles further to the north.

The grey slates of Tarbert, to the south, have here shrunk to the very subordinate position which they generally occupy in Jura. They have, however, been recognised at Camas nam Meanbh-chuileag at the northern extremity of the outcrop. This last-named bay affords a fair exposure also of the main black slate band, while the point to the east consists of massive beds of quartzite, often very

pebbly and in places containing intercalated bands of black slate. At the extreme point there are exceedingly coarse grits with black slate fragments.

For a distance of more than 4 miles to the north of Camas nam Meanbh-chuileag, nothing is seen of the black slate band. The coast, here, consists of quartzites dipping south-east at angles of about 40° and is very straight, no doubt because of the outcrop of the soft black slates just out to sea. At Rudh' a' Bhacain the latter catch on the coast once more. They are, at this point, of a very dark grey shade rather than the full jet-black usually characteristic of the outcrop elsewhere in Jura. They are also banded with dark ribs of siliceous slate.

The chief importance of the Rudh' a' Bhacain exposure lies in the fact that, from its position, it is an obvious connecting link between the band of black slate which extends from it in a S.S.W. direction, to the south end of Jura, and that which extends northward across the Gulf of Corryvreckan, to the east side of Scarba.

Rudh' an Truisealaich, lying between Rudh' a' Bhacain and Kinuachdrach Harbour to the north, largely consists, in its southern portion, of quartzite with subordinate black slate. But the greater part lying to the north is composed of intensely black slates with dark quartzose bands and occasional black limestones. It will be remembered that limestone is not represented in the more southern exposures of the Jura black slates.

The limestones of Rudh' an Truisealaich are rather thin, dark grey or black, and vary from a pure to a sandy and gritty composition, just as do the Loch Awe Limestones of the mainland opposite. The best exposures of these limestones occur due east of the farmhouse of Barnhill, and again on the southern shores of Kinuachdrach Harbour. Slightly north of the first of these two exposures, there is an outcrop of conglomerate on the north shore of a prominent little bay which can be readily identified in the field. The following description may be quoted from Mr. Wilkinson's notes: "In the cliff face, about 15 to 20 ft., pebbles and lenticular masses of derived rock occur embedded in a highly calcareous and cleaved matrix. There are pebbles of beautiful blue and violet and white quartz, limestone, felspars, grit and, I think, a few of pale-coloured granite. Some of the lenticular masses are a foot long. Underneath these beds are flaggy quartzose grits and highly puckered black slates with little quartzite bands." This bed is one of the best examples of conglomerate in the eastern belt of Jura; it is of the pebbly limestone type, so well developed in the Loch Awe Group.

North of Kinuachdrach Harbour there is a prominent little headland, jutting out into the Sound and constituted of gritty quartzites with black slate intercalations. These beds lie east of the main slate band, and therefore correspond to a portion of the well-marked quartzite belt which occupies a like position in southern Jura. The black slate intercalations which break the quartzite succession of this little promontory are much more prominent than their analogues in the Small Isles district. It is probable that this increase of black slate in the composition of the belt has proceeded further in the part hidden beneath the Sound, for it is extremely unlikely that the black

slates of Scarba, to the north, correspond solely to the main black slate band of Jura.

The latter, however, preserves its individuality to the end, so far as the southern island is concerned. North of the Kinuachdrach headland it occupies the coast-line for two-thirds of a mile. The black slates are to some extent interbedded with quartzose bands and quartzite, either dark or light in colour. There are also a couple of small outcrops of dark grey limestone among the slates on the coast. The more southerly is of a pure fine-grained type, while the more northerly, which includes two parallel bands, is in the main of a sandy character. Both outcrops could be matched among the Loch Awe Limestones of the mainland.

It may also be mentioned that limestone is represented in the coast section of quartzite to the north, some 200 yds. west of the boundary of the main black slate band. The thin intercalations, in this instance, consist of a black sandy and pebbly calcareous rock like some of the pebbly limestones of the Loch Awe district. The various bands are separated from one another by jet-black slate and thin quartzite partings.

II.—The Port Ellen Phyllites.

The Port Ellen Phyllites, so called from their type locality in Islay (Sheet 19), are developed in Jura in the form of an extremely sandy set of grey phyllites, associated with many grey foliated sandstones. A few black seams may also be found near the margin of the quartzite to the west. Purer phyllites occur in bands, especially in the eastern portion of the exposures, and are, it happens, flooded with sills of epidiorite.

Although many of these sandy rocks may be somewhat calcareous, definite limy seams are very rare. Sandy and pebbly, pale grey or buff limestone bands have, however, been noticed in two sections, one at the entrance to the Sound of Islay, just to the east of the western boundary of the phyllite group, and another north of Lowlandman's Bay. The bands in the latter section lie, however, about half a mile to the east of the western margin of the phyllites, so that it is doubtful whether they correspond precisely with those seen to the south.

III.—The Epidiorite Sills.

From the Sound of Islay to Lowlandman's Bay intercalated sills of epidiorite are exceedingly numerous. They are restricted to the eastern portion of the Port Ellen Phyllite outcrop. In Mr. Wilkinson's own words: "These eruptive rocks occur in massive sheets and form dark jagged ridges along the coast-line and for some little distance inland. They occur in exactly the same manner as those of Islay. The centre of each sill is generally a coarsely porphyritic rock, which would make a handsome ornamental stone if polished, as it contains large crystals of a pale flesh-coloured felspar scattered through a mottled greenish matrix. Towards the edges the texture of the rock becomes much finer and closer, more schistose and generally of a darker green colour."

Some of the outcrops of these epidiorite sills may be repetitions due to isoclinal folding. In Jura there are no epidiorite sills outside the limits of the Port Ellen group. There are, indeed, cleaved lamprophyric sills among the quartzites outcropping on the west coast, near Rudh' an t-Sàilean, but these are probably of later date than the main folding, and at any rate are very distinct in character from the porphyritic epidiorite of the Small Isles.

Skervuile Lighthouse, in the Sound of Jura, is built upon a fine-grained non-porphyritic epidiorite, while Na Cuiltean, to the south, consists of outcrops of highly porphyritic epidiorite. It seems likely that these two islets represent sheets belonging to the same series as those of south-west Jura.

IV.—The Epidiorite Dykes.

The epidiorite dykes of Jura attain their maximum development in the extreme north of the island, and reappear in Scarba across the Gulf. Most of them lie in Sheet 36, and have been dealt with already in the corresponding memoir. They usually run north and south, but a few strike N.N.W. and S.S.E., while three, according to Mr. Wilkinson's mapping, form a group with an east and west trend, crossing the island about two miles north of Tarbert Bay. In the southern half of Jura, Mr. Wilkinson has mapped a north and south dyke reaching the Sound of Islay a mile and a half west of Jura House.

Individually the dykes are broad and run vertically through the tilted quartzite. Their schistosity, which is parallel with their margins, is often very imperfect; it is obviously due to some late recurrence of movement, posterior to the folding which tilted the quartzite.

E. B. B.

Petrology.—Most of the specimens examined microscopically are rather fine-grained and not very schistose. They consist of the usual minerals of epidiorites, namely, hornblende, epidote, albite, apatite, iron-oxides and leucoxene. Biotite also, some clearly secondary, is very common in these rocks. All the more massive specimens show ophitic structure very well preserved, but the original augite is entirely converted into uralite with some chlorite, epidote and biotite. The hornblende is rather pale green and rarely well crystallised; often it forms dense aggregates with chlorite, secondary green biotite and yellow epidote. As these rocks are not much sheared the iron oxides often retain their reticulate shapes, though they may be wholly converted into leucoxene. Bright green uniaxial biotite is remarkably common in these diabases, and its abundance is one of their characteristic features: it is strongly pleochroic in colours ranging from deep green to pale yellow, and is often mixed with chlorite and epidote in such a way as to prove that it is secondary. Large well-formed crystals of this mineral also occur, and it is not always certain that some of them may not be primary. The felspar is albite, often richly charged with granular epidote. Quartz appears in small quantity, but cannot be shown to be original. Carbonates also are scanty.

J. S. F.

Structure.

Regarding the tectonics of Jura there is little upon which one can express a confident opinion. The various divisions of the sedimentary schists succeed one another in an apparent upward structural succession from north-west to south-east. No important faults have been recognised except those described in the neighbourhood of Inver Cottage, on the Sound of Islay. The impression derived from an examination of the island is one of extreme simplicity. If, however, this impression is not fallacious, the thickness of the Jura Quartzite must be admitted to be not less than 15,000 ft. Still, after careful scrutiny of the coast sections and an inspection of the bare rock faces of the Paps, no evidence was found of isoclinal repetition by folding. It seems probable that, if there is anything like constant isoclinal repetition within the mass of the quartzite, it is due rather to thrusting than to folding. Several suspicious-looking planes were, indeed, met with during the tour of the coast-line, but it was not found possible to ascertain their proper significance; in certain cases, in fact, upon close examination, they appeared to be planes of false-bedding and quite unconnected with subsequent deformation.

The folding movements, which have affected the rocks of the island, have not only tilted the strata at moderately high inclinations, but have also impressed a well-marked cleavage upon their less resistant members. This is exemplified in the case of the semi-pelitic flaggy intercalations, so common in the quartzite of the northern half of the island; sometimes, also, in the quartzite itself, especially towards the east coast; and, finally, in the slates, phyllites and epidiorite sills which fringe that coast and are lost sight of beneath the waters of the Sound of Jura.

The slates and phyllites of the eastern shores, in accordance with their more yielding nature, show an infinite number of rucks and minor isoclinal foldings, in marked contrast to the orderly inclination of the massive quartzites to the west. They are, moreover, frequently traversed by a conspicuous second cleavage. This latter is of the obvious strain-slip type, and strongly suggests a repetition of powerful earth movement in the history of the island's tectonic development.* The cleavage of the lamprophyric sills near Rudh' an t-Sailean may have originated during some such recrudescence of folding movement.

The shearing of the epidiorite dykes stands on a different footing. It is parallel to the dyke margins and may be due to local readjustments unaccompanied by any general development of cleavage structures in the country outside. All that seems certain is that it is later than the main folding, for the dykes are vertical.

E. B. B.

* Cf. C. T. Clough, "The Geology of Cowal," *Mem. Geol. Survey*, 1897; and W. B. Wright, "The Two Earth-Movements of Colonsay," *Quart. Journ. Geol. Soc.*, 1908, vol. lxiv. pp. 297–312.

CHAPTER X.

LATER IGNEOUS ROCKS.

Lavas of Glas Eilean, Jura.

Glas Eilean is a small island in the Sound of Islay, at low tide almost connected with Jura (Fig. 5). Macculloch * long ago made the discovery that it consists of amygdaloidal lavas, and suggested a possible connection between these lavas and the basaltic dykes so abundantly developed in the neighbouring portions of Jura and Islay. Macculloch's observations were lost sight of, and for a time the lavas of Glas Eilean were forgotten. In 1897, however, the volcanic rocks were rediscovered by Mr. Wilkinson,† who noted their association with red and white calcareous sandstones, possibly of Lower Old Red Sandstone age. In the following year Sir Archibald Geikie ‡ visited the island and obtained evidence in support of the view that the lavas belong to the same Lower Old Red Sandstone series as those of Lorne: "They show abundantly a true slaggy structure, their vesicles being commonly filled with calcite. A conspicuous feature among them links them with the volcanic series of Lorne and of the Lower Old Red Sandstone of Central Scotland, namely, the abundance of veinings and irregular layers and nests of pale and red fine sandstone. Some parts of the lava have been entirely broken up into masses of slag between which the sandy sediment has accumulated, precisely as may be seen on the coast sections at the Red Head of Forfarshire, Turnberry Point in Ayrshire, and many sections round Oban."

The lavas occur in several successive sheets, separated by grassy hollows and dipping away from Jura at about 30°, and form long reefs exposed at low water.

If the correlation of these lavas with the Lower Old Red Sandstone volcanic rocks be correct, then, of course, Macculloch's suggested connection with the North-West dykes falls to the ground. The point is one of great interest and deserves further consideration; in fact, the presence of these lavas in the Sound of Islay suggests many inquiries, the answering of which must be left to the future.

Dykes and Intrusive Sheets.

The non-schistose igneous rocks of the district, other than those of Glas Eilean, fall naturally into three groups:—

* "A Description of the Western Islands of Scotland, including the Isle of Man," 1819, p. 213.

† *Sum. Prog. Geol. Survey* for 1897 (1898), p. 64.

‡ *Sum. Prog. Geol. Survey* for 1898 (1899), p. 75.

North-West Dykes of fine-grained Dolerite or Basalt, probably of early Tertiary Age.

East and West Quartz Dolerite Dykes, probably of Permo-Carboniferous Age.

Sheets and Dykes of Lamprophyre, Porphyrite and Felsite, probably of Lower Old Red Sandstone Age. E. B. B.

The area now described has only afforded one important clue in regard to the age of these three sets of dykes: in two cases East and West quartz dolerite dykes are seen to be cut by other dykes belonging to the North-West series; the one case is in Abhainn Mhor, between Loch Caolisport and Loch Sween (12527 cuts 12525), and the other is to the north of Loch Racadal, between West Loch Tarbert and Kilberry Head (13334 cuts 13333). Now, the East and West quartz dolerite dykes form a very well-defined set of igneous intrusions in the southern half of Scotland, and are, as Fig. 6 indicates, manifestly later than some part at least of the Coal Measures. The evidence of the Abhainn Mhor and Loch Racadal instances thus furnishes support to the view that the particular North-West dykes, occurring in the area under discussion, are really of Tertiary age.

Hitherto, indeed, it has been generally assumed that the North-West dykes of the West Highlands belong to one suite of intrusions, and are therefore Tertiary like those of Skye. Since, however, Dr. Flett has shown that many North-West dykes, in certain parts of the West Highlands, including Knapdale and Jura, are of types practically unknown among the carefully-studied intrusions of Skye, the necessity for caution has been recognised. The dykes in question have an alkali tendency, shown by the prevalence of purple augite and such accessories as analcite. They recall in certain respects the products of vulcanicity of the Carboniferous period, and it was felt that they might actually belong to that epoch, and that their parallelism with undoubted Tertiary dykes might be merely a coincidence.

The Abhainn Mhor and Loch Racadal evidence disposes of this possibility, and accordingly strengthens the position of those who regard all the North-West dykes as Tertiary. E. B. B., G. W. G.

No evidence has been found in this district bearing upon the age of the lamprophyre, porphyrite and felsite sheets and dykes, except that a cleaved lamprophyre sheet* near Rudh' an t-Sàilean, in Jura, is seen cut by one of the North-West dolerites. To the north, however, their position in the "Newer Granite" suite of intrusions has been demonstrated, and it has also been shown that this suite of intrusions belongs, at least in part, to the Lower Old Red Sandstone period.

The evidence in regard to the Late or Permo-Carboniferous age of the East and West quartz dolerite dykes has been for the most part obtained by Mr. Clough. A full discussion of this interesting question will be found on reference to the second edition of the

* These cleaved lamprophyres of Rudh' an t-Sàilean may belong to a decidedly earlier period than their uncleaved analogues.

Geological Survey Memoir on the Neighbourhood of Edinburgh. The main point in the argument there set forth is the connection which almost undoubtedly exists between these East and West dykes and certain quartz dolerite sills, which have shared in the folding and faulting of the Carboniferous strata of the Central Valley.

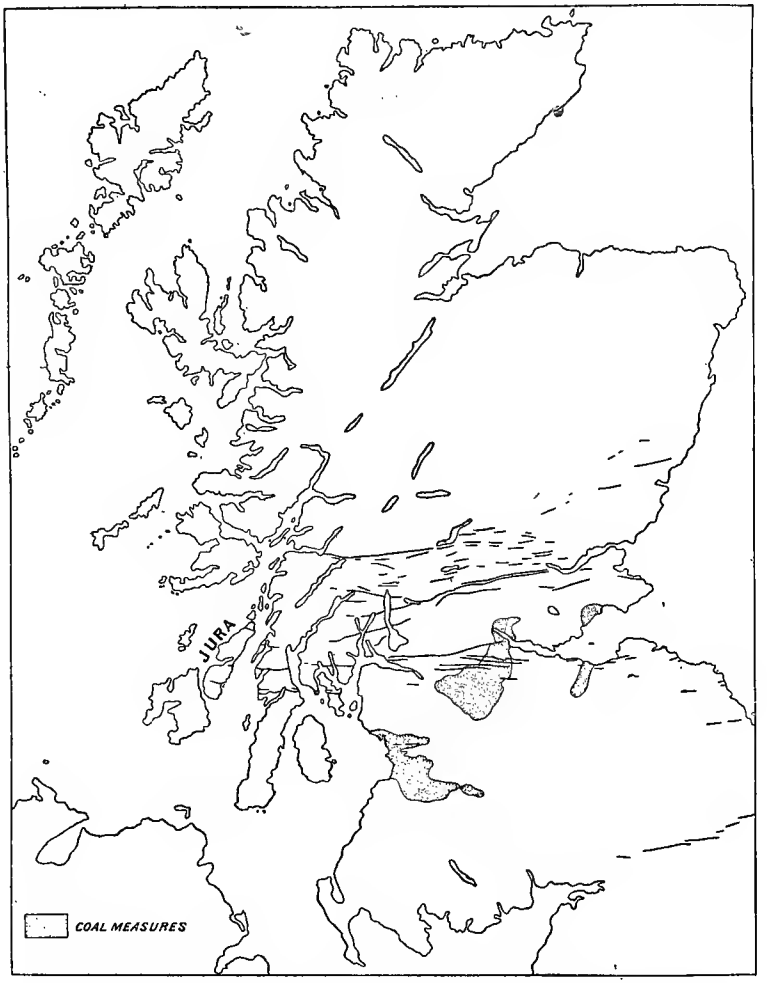

FIG. 6.—Sketch Map of East and West Quartz Dolerite Dykes of (?) Permo-Carboniferous Age.

With regard to the North-West dykes of the district it has already been shown that the local evidence strongly favours the view that they are of Tertiary age. E. B. B.

LAMPROPHYRES, PORPHYRITES AND FELSITES.

Mainland.—These rocks, representing a portion of the dyke phase of the Newer Granites of the Highlands, are of exceptional

occurrence in this region, the only examples detected being dykes of porphyrite, near the end of the central fiord at the head of Loch Sween, and a few lamprophyre sheets on the coast of Loch Fyne, between Artilligan and Stronchullin. Close to Artilligan a band, from 8 to 10 ft. in thickness and with a texture resembling basalt, is intercalated between beds of compact quartz schist; it contains hornblende, augite and felspar (3349). A quarter of a mile north of the Artilligan Burn two sills, varying from 2 to 4 ft. in thickness, occur close together on the shore. They are dark in colour and of fine texture, and contain numerous ocelli of red felspar which range from the smallest grains to patches 6 or 7 in. in size. A sill of the same dimensions is seen on the shore at Nead an Fhithich,* apparently on almost the same strike as a similar outcrop in the Artilligan Burn about a quarter of a mile from the coast. Another sheet, from 6 in. to 1 ft. in thickness, appears on the coast a quarter of a mile still further north, while a small wedge-like mass, that occurs half a mile south-east of Stronchullin, probably also belongs to the same class.

The connection between these Knapdale intrusions and the Newer Granites of the Highlands has been shown in the region bordering Upper Loch Fyne. Here dykes of the same type are represented amongst the lamprophyre group in the tract lying between Glen Shira and Glen Fyne (Sheet 37), and are shown, by intermediate connecting links, to be genetically related with the granite.† J. B. H.

Jura.—Mr. Wilkinson found lamprophyre sills fairly numerous in the northern portion of Jura. They follow the inclined bedding planes of the quartzite into which they are intruded. As they present no points of special interest, it is unnecessary here to repeat the description already given in the explanation of Sheet 36. Within the part of the island included in Sheet 28, Mr. Wilkinson has noted the presence of lamprophyres near the coast at Tarbert and Corrynahera, and also on the south-east slope of Maol nan Damh, two miles west of Ardlussa. The last of these is a beautiful example of a red mica-trap. It outcrops as a narrow ridge running parallel to the strike of the quartzite.

Perhaps the cleaved lamprophyres near Rudh' an t-Sàilean are early representatives of this Old Red Sandstone set of intrusions, but they may be of independent origin. They behave as sills following the bedding of the quartzite, which is tilted at moderate angles. The cleavage affecting them is steep and regular.

Porphyrites are rather plentiful at Ardlussa (Sheet 28), Lealt and Barnhill (both in Sheet 36). They occur in the form of steeply inclined sheets following the bedding or cleavage, and outcrop as ridges.

A small dyke of quartz felsite also occurs on the shore-line of the Aird of Kinuachdrach (Sheet 36). It is 4 ft. wide and pale pinkish buff in colour. E. B. B.

* Three-quarters of a mile north of Artilligan.

† See paper by J. B. Hill and H. Kynaston, "On Kentallenite and its Relations to other Igneous Rocks in Argyllshire," *Quart. Journ. Geol. Soc.*, 1900, vol. lvi. p. 531; and "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, pp. 94–98 and 106–110.

EAST AND WEST QUARTZ DOLERITE DYKES.

An important feature of this suite of intrusions is their tendency to be of considerable breadth, often 20 or 30 yds. wide, and to be correspondingly coarse in texture.

Mainland.—The most northerly dyke of the series has been traced from near Loch nam Breac Buidhe, across Loch Sween, through Tayvallich and out into the Sound of Jura at Eilean Dubh.

B. N. P.

Further to the south, another, which corresponds in direction to the Dunoon Castle dyke that has been traced through Cowal, crosses Knapdale between Mounterins on Loch Fyne and the entrance of Loch Sween. The portion which lies between Loch Fyne and Eas Dubh has an average breadth of about 20 yds. It is not continuously exposed at the surface along this distance, but the constancy of direction assumed by the outcrops is such that there need be little hesitation in accepting their subterranean connection.

J. B. H.

Between Eas Dubh and Loch Caolisport the dyke obviously coincides with an east and west line of fault. To the south of the dyke, about a quarter of a mile north-east of Loch a' Chaoruinn, there is another intrusion in the form of a horizontal sheet, jointed into rude vertical columns. The rock is traversed by pink veins in the same way as the quartz dolerite sheets of the Lothians. Though we have no evidence of the relations of this sheet to any of the dykes, the petrographical constitution leads us to suppose that it is late Carboniferous in age, and is related to the East and West dykes.

G. W. G.

A thin basaltic dyke, 2 or 3 ft. thick, which crosses Eilean Fada in an east and west direction, is probably of the same age as the broad dyke of Eas Dubh, from the submarine continuation of which it is probably only about 150 yds. distant. It has on its south side a line of crush with veins of calcite, but seems itself quite free from crushing.

The main Eas Dubh dyke reaches the west shore of Loch Caolisport to the north of Ellary, and has been quarried here on the north side of a raised beach. It is at least 16 yds. in breadth. A specimen from the central part proved to have a specific gravity of 2·97. The phyllites on the north side are considerably hardened and changed in colour from the usual pale or greenish grey into dark grey. A crush breccia on this side has also been hardened. No evidence of crushing was observed in the dyke itself.

C. T. C.

In Abhainn Mhor the dyke is cut by one of the North-West basalts; the significance of this relation has already been discussed.

G. W. G.

Between Abhainn Mhor and Loch Sween the dyke is about 20 yds. broad. It reappears in the entrance to the loch, in Sgeir Bun an Locha, where its great breadth is well displayed.

B. N. P., J. S. G. W.

Two other dykes which traverse the northern part of Kintyre

(Sheet 29) appear from their direction to represent the two which cross Ardlamont Point and the island of Bute. The most northerly of these dykes appears at Fionn, and is represented on the shore by a few small tongues 3 or 4 ft. in width. These merge into a wider mass, which pursues a westerly direction for a third of a mile, gradually increasing to a breadth of from 30 to 40 yds. Its course is then deflected to the west-north-west, and the breadth dwindles to 25 ft. At a distance of three-quarters of a mile from the coast it abruptly dies out, but reappears at the surface in a few small exposures for another quarter of a mile. Beyond this all trace of it is lost, unless, as is possible, a small outcrop, 20 yds. in breadth, which occurs at Cruach an t-Sorchain, about three-quarters of a mile further to the west, may represent the same intrusion. The rock has been much altered and is of a greenish hue in consequence of abundant serpentinous products of decomposition, and is, therefore, most appropriately described as a diabase. It has effected contact alteration on the adjacent schists, which are indurated and considerably discoloured near the margin.

The dyke to the south is also frequently much decomposed. At Rudha Grianain,* on the coast of Loch Fyne, it has a breadth of from 50 to 60 yds., but from this point, following a course a little north of west, it gradually contracts to a width of about 30 yds. Before reaching the small stream running northwards towards Fionn, however, it expands to a width of 130 yds. and ends off against a fault along the bed of the burn. About 80 yds. further up the stream, it is seen on the western bank reduced to its normal dimensions and pointing north-easterly, in the direction of the bigger mass below. This dyke is apparently not displaced by the fault, but owes its diversion to the presence of a pre-existing fracture.† Soon after being freed from the influence of the fissure, it reverts to its normal westerly course for a quarter of a mile, when it is diverted to the north-west for a similar distance. Presently, however, it bends round to the westward and continues in that direction until it finally disappears north of Cruach Doire Leithe. The termination of this band is coincident with the oncoming of another of similar breadth (20 yds.) about a third of a mile to the south, which pursues a west-north-west course until, sweeping round to the westward, it occupies the exact path that would have been followed by the northerly band had it continued its course to the west; the two bands may, therefore, be confidently referred to the same intrusion. After its appearance, the southern dyke rapidly increases to a width of about 50 yds. On reaching Allt Tarsuinn its continuity is again disturbed by meeting a fault. Here, not only does it bend to the west-north-west, but it also divides into two parallel bands about 20 yds. apart, the smaller of which is about 15 yds. across. Moreover, in crossing this faulted area it has incorporated fragments of quartz schist, the detachment of which in the fractured zone facilitated their inclusion in the ascending magma. The area of disturbance extends for about a quarter of a mile, when the dyke

* About two-thirds of a mile south-east of Lagganroaig.

† Mr. Clough has described similar deflections in "The Geology of Cowal," *Mem. Geol. Survey*, 1897, p. 143.

reappears on the hillside with normal dimensions and trend, in the position it would have occupied if its continuity had been unbroken. It reaches the coast of West Loch Tarbert (Sheet 28) at the mouth of Abhainn Bardaravine, about a quarter of a mile to the north of Rhu, where it is about 50 yds. broad and exhibits a coarse transverse prismatic jointing, while a small limestone in contact with it shows evidence of baking. The dyke reappears on the opposite shore with similar characters and dimensions, and is again seen in the stream in Gleann Fithich, where it is nearly 70 yds. broad. Between that locality and the coast, it has not been traced; but, as the intervening ground is largely occupied by peat and timber, it may be present, especially as small outcrops of basalt have been recognised in the woodland tract. J. B. H.

From Gleann Fithich to Loch Caoi-rain the dyke follows a west-north-west fault line, but at the loch resumes its original east and west course and runs somewhat to the north of Loch Racadal. Lack of exposure along Allt Caoi-rain renders it uncertain whether the east-north-east and east and west portions of the dyke have a surface connection (as suggested on the map) or no. The exposure north of Loch Racadal, in which one of the North-West dykes cuts the East and West dolerite, has already been referred to. E. B. B.

The continuation of the dyke to the sea at Cretshengan Bay is easily traced. A mile from the coast its direction is crossed by a North-West dyke, but the mutual relations of the two could not be determined.

From Loch nan Torran westwards, another East and West dyke has been traced about a mile to the north. J. S. G. W.

Jura.—Two possible representatives of the East and West dolerite dykes of Jura have already been described in the Explanation of Sheet 36 (p. 84). One of these forms a grand feature in the cliffs at the extreme north of the island, while the other appears about 2 miles further south, on the east coast at Con Tom, and has been traced by Mr. Wilkinson in a W.N.W. direction, right across the island, to the west shore.

In Sheet 28, a little north of Lagg Bay, Mr. Wilkinson has picked out another dyke evidently belonging to the series, and representing the continuation of the one which crosses the mouth of Loch Sween.

Lastly, a massive, broad East and West dolerite dyke forms part of the landing stage of Faolin House, and is no doubt a continuation of the intrusion that reached the other side of the Sound of Jura at Cretshengan Bay. The probable inland course of this dyke has been traced by Mr. Wilkinson in a general west-north-westerly direction to Lochan Gleann Asdale. E. B. B.

Petrology.—The East and West or older dolerite dykes of this district are quartz dolerites or quartz diabases of very typical character. They are often coarse-grained and present all the features of this group of rocks in great perfection. A comparison with the East and West dykes of the Cowal area shows that there can be no doubt they belong to the same series.* Moreover, they present the

* "The Geology of Cowal," *Mem. Geol. Survey*, 1897, p. 147.

closest resemblance to the quartz dolerites of the West Lothian area described by Dr. Falconer,* and also in the second edition of the *Geological Survey Memoir* on the Neighbourhood of Edinburgh. In the districts which lie both north and south of the area comprised within Sheet 28, intrusions of quartz dolerite occur, with tholeiites etc., which have been ascribed to the Tertiary eruptions in the West of Scotland.† It is often not difficult, however, to separate these latter by their petrographical characters from the earlier Permo-Carboniferous types, for though they consist of the same minerals they differ in points of structure. Consequently we arrive at the conclusion that rocks of this group have been produced in two distinct epochs of igneous activity in this part of Scotland. The Permo-Carboniferous dykes are generally much decomposed, while the Tertiary dolerites are often in an excellent state of preservation.

The quartz diabases consist essentially of pyroxene, plagioclase felspar and micropegmatite. The pyroxene tends to occur in two forms, namely, as long prismatic crystals and in ophitic irregular masses. The prismatic pyroxene is generally altered to deep green chlorite, iddingsite or bastite, but where it is fresh it proves to be of two kinds. Some rocks contain hypersthene in this form, never well preserved, but only as kernels in masses of bastite. It has little colour or pleochroism, but in convergent light (10183) proves to be optically negative with a large axial angle. The other prismatic pyroxene is monoclinic, often simply twinned on the orthopinakoid; its long, narrow crystals have high extinction angles, and where they weather they develop a herring-bone structure. They (10183) recall the so-called sahlite in the quartz dolerites of Arran described by Corstorphine;‡ this augite is optically positive. The ophitic augite is not idiomorphic except where it is in contact with micropegmatite. Its colour is always pale brown; sometimes it is nearly colourless. A slight zonal structure may often be noticed, especially between crossed nicols. It frequently shows a fine lamination, apparently parallel to the basal plane, and this is emphasised by weathering, as chlorite and uralite seem to originate readily along these laminæ. This augite has mostly a very large axial angle, but it varies a good deal in this respect, and in some portions of the crystals the angle is small for a pyroxene. (Similar variations in the augites of quartz diabases have been described by Hovey and Wahl.§)

The plagioclase occurs as broad laths embedded in augite. Its crystals are very highly zonal, and range in composition from basic labradorite or bytownite at their centres to oligoclase albite in a thin external border. Alkali felspar (usually untwinned and probably for the most part orthoclase), micropegmatite and quartz occur interstitially.

A little pale brown hornblende, brown biotite (usually not very dark coloured), apatite and titaniferous iron oxides in large plates are the other primary ingredients. Secondary green uralitic hornblende,

* "The Igneous Geology of the Bathgate and Linlithgow Hills," *Trans. Roy. Soc. Edin.*, 1908, vol. xlv. p. 133.

† "The Geology of North Arran," *Mem. Geol. Survey*, 1903, p. 111; "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909, pp. 86–88.

‡ *Tschermak's Min. Pet. Mittheil.*, vol. xiv., 1895, p. 465.

§ E. Wahl, "Die Enstatitaugite" (Helsingfors), 1906; also *Tschermak's Min. Pet. Mittheil.*, vol. xxvi., 1907, p. 1.

chlorite, carbonates, bastite and limonite are usually abundant. The felspars are often filled with scales of secondary white mica.

Some of these rocks contain so little quartz that they are better called hypersthene diabases. A large dyke of this type occurs at Lagg, in the island of Jura. It is specially interesting, as it contains three varieties of pyroxene : (*a*) hypersthene, optically negative, nearly completely decomposed; (*b*) enstatite-augite in long narrow prisms, often bent, and twinned on the orthopinakoid. It has an extinction angle of nearly 45°, but in convergent light is positive with a small axial angle, about 12°; (*c*) pale brown ophitic augite, mostly with a

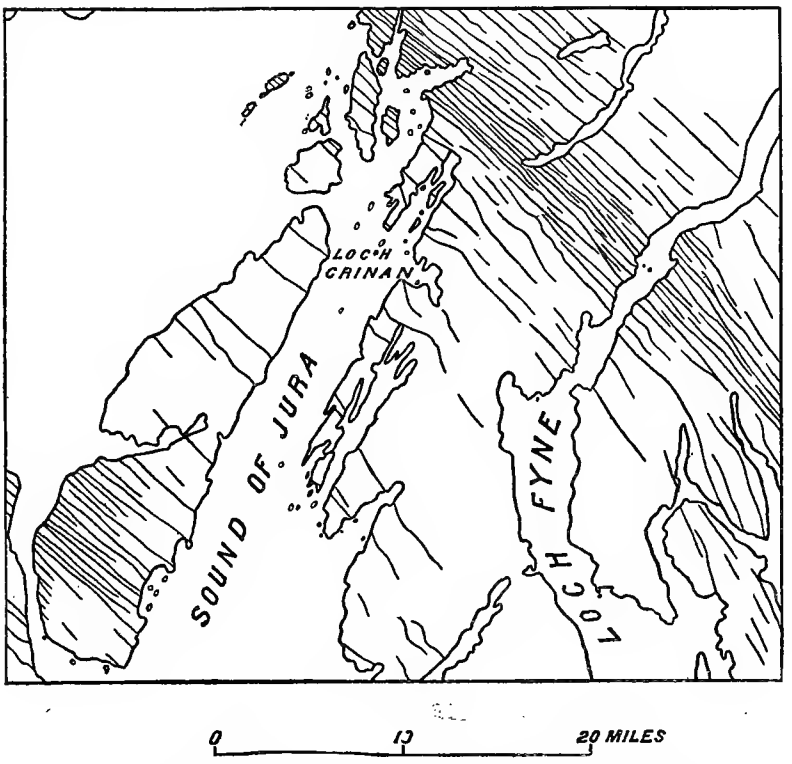

FIG. 7.—Sketch Map of North-West Dolerite Dykes of South-West Highlands.

large axial angle (2.E. about 105°), but variable in different portions of the same crystal. J. S. F.

NORTH-WEST DOLERITE DYKES.

Field Relations.—A glance at Fig. 7 will show that the North-West series of dykes is but sparingly represented throughout Knapdale, but that a rich belt of them has been mapped by Mr. Wilkinson crossing Southern Jura. Along the western shores of this romantic island the waves have laid bare the resistant basalt dykes, so that these now stand sometimes as great walls, sometimes as arches and

at others as isolated stacks, diversifying in their fantastic array the rugged shelf of the lowest raised beach and running out across it into the sea (Plate VI.). Inland in Jura they not infrequently make conspicuous features too, although these cannot of course compare with the grand display of the coast-line.

The main point in regard to the field relations of these North-West dykes, taking the area as a whole, has already been dwelt upon: in Abhainn Mhor, and again at Loch Racadal, examples of the group are seen clearly cutting East and West quartz dolerites.

Beyond this, the most interesting feature is the crooked nature of the dykes. This character is undoubtedly dependent upon the tendency, which dykes constantly show, to follow earlier lines of weakness. The dyke north of Loch Racadal is itself a very good example of the effects of this tendency. This point is further illustrated in Mr. Clough's accounts of the faults occurring near the head of Loch Caolisport (see Chap. XI.).

The North-West dykes do not, as a rule, measure more than a few yards across, and generally they are basaltic rather than doleritic in texture. They are also fresher than the East and West dolerites; but whether this is due to their more recent origin or their less crystalline texture, is not quite clear. Some little way in from their margins, they frequently show lines of round vesicles often filled with zeolites. Their edges are compact or vitreous, and the schists in contact with them are more or less hardened and altered. A not uncommon appearance, among these dykes, is a pseudo-spherulitic type of weathering. There is reason to believe that this is connected with the presence of analcite, but the *rationale* of the supposed connection is quite obscure. E. B. B., G. W. G.

Petrology.—The North-West dykes of southern Jura and the adjacent parts of Argyllshire are olivine dolerites and analcite olivine dolerites. They consist of olivine, augite and plagioclase felspar with apatite, iron oxides and other accessories, and in the analcite dolerites there are considerable amounts of analcite and of natrolite. The two groups can hardly be separated from one another, as they are identical in their structures and the characters of their minerals; they occur together in such a way as to show that they are closely related; for example, there are eight dykes of this series near the mouth of Allt Bun an Eas, in Jura, and of these one half belong to one class and the remainder to the other.

These dykes differ from the usual type of Tertiary dolerites such as occur in Skye in several respects, and by their properties they approach the basic nepheline and analcite rocks which are known as theralites and teschenites. In other parts of the county (Colonsay) they are accompanied by monchiquites, an association which, if not accidental, clearly indicates their theralitic affinities.

These rocks are seldom porphyritic. They are fine-grained and possess ophitic structure in the greatest perfection, in fact, no better examples of ophitic rocks could be adduced from any part of Britain. The felspar nearly always gives lath-shaped sections which show albite (rarely pericline or Carlsbad) twinning; they are for the most part labradorite, but are somewhat zonal, and their outward portions have low extinction angles. In many of the slides a very small

Dolerite Dykes. Between Brein Phort and Allt Bun an Eas, West Coast of Jura.

amount of alkali felspar with lower indices of refraction than Canada balsam, can be found surrounding the lime-soda felspars or inserted between them. The olivine is in small grains, often very fresh, and contains magnetite and small brown grains of chromite. The augite is of the variety which is described as titaniferous, with purple and violet colours, distinct dichroism and marked dispersion of one of the optic axes. Of all the essential minerals, the felspar is the most idiomorphic; the augite occurs only as large plates which are penetrated by laths of felspar in all directions, and it is by no means uncommon to see the olivine also enclosing plagioclase, at any rate in the outer parts of its crystals, though not in their centres. The irregular plates of iron oxide also sometimes envelop the ends of crystals of felspar.

In the analcite dolerites the ophitic structure is hardly less perfect than in the olivine dolerites, but sometimes a part of the augite may show crystalline form. The augite has the same rich purple colour, and often in polarised light exhibits zonal and hour-glass structures. Natrolite and analcite occur in interstitial patches and in rounded steam cavities; the analcite may be turbid or quite clear and colourless; the natrolite forms radiate spherulitic groups or granular aggregates without crystalline faces. As the felspars are sometimes completely fresh, it is difficult to believe that these minerals have been derived from them; on the other hand, there is no trace of nepheline, and the zeolites have not the arrangement which results from the alteration of nepheline where that mineral has been present in the Scotch theralites and teschenites. Hence we may assume that they are not really secondary, but belong to a pneumatolytic stage in the crystallisation of the rocks at a time when the temperature had fallen greatly, and the vapours of the magma combined with other ingredients to form hydrous minerals. At the same time, there is a secondary analcite which may be seen to spread inwards through the felspars, veining them and gradually replacing them. Small rounded steam cavities also occur completely filled with these minerals (Plate V. Fig. 5).

For several reasons it seems worth while to give these analcite dolerites a special name. The presence of primary analcite distinguishes them from the ordinary olivine dolerites of the West of Scotland; they occur in great numbers in Jura, Colonsay and northern Argyllshire, and have very constant characters. We propose to call them "Crinanites" (Plate V. Fig. 5) from Loch Crinan, which is almost in the centre of their area of distribution. They present some analogies to the teschenites in mineral composition; from these latter they are distinguished by their finer grain, their perfect ophitic structure, the scarcity of hornblende and biotite, and their occurrence as thin vertical parallel dykes.

An analysis of one of the Jura analcite dolerites or crinanites (Plate V. Fig. 5) has been made by Mr. E. G. Radley in the Survey's laboratory and is given below (I.). It shows that the rock is of thoroughly basic character, and by no means rich in alkalies (3 per cent.). Its special features are the high percentage of titanium (recalling the camptonites), and the comparatively large amounts of lime, magnesia and iron. On the whole, the rock has closer affinities chemically with the olivine dolerites than with the teschenites,

camptonites or monchiquites. For comparision we quote an analysis of a Tertiary dolerite from Skye (II.), and of the camptonite of Ardmucknish (III.). Of all the basic rocks of Scotland which have been analysed, the analcite basalt of Hillhouse, near Linlithgow (IV.), is the one which presents the closest similarity to the Jura crinanite.

	I.	II.	III.	IV.
SiO_2	43·94	44·01	42·22	42·49
TiO_2	2·45	1·66	2·49	2·51
Al_2O_3	14·03	12·69	10·62	13·85
Fe_2O_3	1·95	3·62	4·74	2·59
Cr_2O_3	trace	trace	0·10	—
V_2O_3	undet.	undet.	0·05	—
FeO	11·65	8·75	6·18	9·32
MnO	0·32	0·21	0·50	0·29
(CoNi)O	nt. fd.	trace	0·05	0·09
BaO	nt. fd.	—	0·04	0·04
SrO	nt. fd.	—	nt. fd.	—
CaO	8·99	10·57	14·80	9·76
MgO	10·46	12·86	8·68	11·21
K_2O	0·33	0·49	1·41	0·87
Na_2O	2·68	1·68	2·46	2·39
Li_2O	nt. fd.	—	? trace	nt. fd.
H_2O at 105°	0·85	0·89	0·50	0·47
H_2O above 105°	2·31	2·73	1·16	3·35
P_2O_5	0·20	0·17	0·73	0·61
FeS_2	0·04	—	—	nt. fd.
Fe_7S_8	0·06	—	—	—
CO_2	0·16	trace	3·57	0·22
S	—	0·11	0·12	—
Total	100·42	100·44	100·42	100·06

I. Crinanite or analcite dolerite (14174). Slac nan Sgarbh, 1 mile north of Inver Cottage, Jura (Sheet 27). Analysis by E. G. Radley.

II. Porphyritic olivine dolerite (7862), dyke cutting granite. Ciche na Beinne Deirge, Skye. Analysis by W. Pollard; cited from A. Harker, "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, p. 325.

III. Camptonite (11817). Sailean Sligenach, Ardmucknish, Argyllshire. Analysis by E. G. Radley; cited from "The Geology of the Country around Oban and Dalmally," *Mem. Geol. Survey*, 1908, p. 126.

IV. Analcite basalt (14075). Hillhouse Quarry, 1½ mile south of Linlithgow, the sill above the limestone. Analysis by E. G. Radley. J. S. F.

CHAPTER XI.

FAULTS.

Two main fault directions are recognisable in the map, namely, north-west and east and west. It is interesting to notice that both directions were represented at the epoch of intrusion of the Late or Permo-Carboniferous quartz dolerite dykes: thus, south of Loch Caoi-rain, between Kilberry and Loch Tarbert, a north-west fault leads to the local deflection of a typical "East and West" quartz dolerite dyke, while, south of the Baranlongart Burn, another example of the same set of intrusions follows an east and west fault, and, near Ellary, on the other side of Loch Caolisport, obviously indurates a breccia (p. 111), which probably belongs to the western continuation of the fault. C. T. C., E. B. B.

Perhaps the most important fault, that occurs in this region, is that which runs along the hollow between Crinan and Lochgilphead (Sheet 29). On its north-eastern side it displaces the boundary between the Loch Awe and Ardrishaig Groups, about half a mile to the south-east. On the south side of Lochgilphead this fault must change into a nearly southerly direction. Still further south, it is perhaps the main cause of an apparent displacement of about three-quarters of a mile, the north-east side again towards the south-east, which seems indicated by a comparison of the positions of the Green Beds at Stonefield and Ardmarnock respectively, on opposite sides of Loch Fyne. J. B. H.

The next important fault to the south is that of the Lussa. The western continuation of this fault is doubtful, but it seems likely that it is responsible for the pass, or "bealach," from which Tayvallich receives its name.

The shattering of the rocks along the course of the Lussa fault has given rise to a very important transverse feature of erosion connecting Ardlussa and Inverneil. The shift of the outcrops produced by the fault is in the same direction and of about the same amount as that due to the Crinan fault: thus, the boundary of the Loch Awe and Ardrishaig Groups lies about half a mile further to the south-east on the north-east side of the fault than on the south-west.

The Lussa fault is joined, in the Inverneil Burn, by an east and west branch, which has determined the course of the Eas Daltot and the upper and more picturesque portion of the Easan Tom Luirg. The shift in the boundary of the Loch Awe Group, due to this fault, is about a quarter of a mile in the same direction as before mentioned.

In the fault block between the Lussa and Eas Daltot, two strike faults are shown upon the map. The evidence for the existence of these is stratigraphical, and is discussed in the chapters dealing with the Ardrishaig and Loch Awe Groups. It is likely that their origin is closely linked with the folding movements. E. B. B.

The Lussa fault in the Inverneil Burn displaces the margin of the Erins Quartzite Group about half a mile, the north-east side to the south-east. This fault is probably dying out in the direction of Cowal, as the only fault on the opposite coast of Loch Fyne to which it seems likely to correspond is that of Port Leathan, which has a displacement in a similar direction of about 400 yds.

To the south-west of Inverneil, a fault parallel to the Lussa fault follows the stream which joins Allt nan Nathair at the foot of Cruach Mheadhonach.

Between Inverneil and Stronchullin (Sheet 29) a north-easterly fissure, carrying a large vein of chalybite, runs along the bed of the burn which meets the coast a quarter of a mile north of Creagan Beag.

A north and south fault, accompanied by a vein of white quartz and a later basalt dyke, occupies the channel of the stream that flows through Gleann dà Leirg (Sheet 28).

Another fault, with a north-east trend, has been brought out by Mr. Bailey's mapping of the Stronchullin phyllite; it crosses the glen above mentioned to the north of Stuchd Bhreac. About a mile further south, an east and west fault runs along the bed of a tributary stream of the Artilligan Burn. J. B. H.

As the Eas Daltot fault to the north, so also most of the faults near the head of Loch Caolisport strike nearly east and west; they are, however, neither numerous nor large.

The hardened crush breccia at the side of the East and West dolerite dyke near Ellary has been already mentioned (pp. 111, 119), and is of some interest, as it must evidently have been formed before the cooling of the dyke, if not before its intrusion. It inclines north, and most of the other east and west faults in the district appear also to downthrow in this direction. Two of them cross an epidiorite sill just west of Gleann Tarsuinn, and each displaces the outcrop about 16 yds., the north side towards the east. These unite to the east, and have determined the lower part of the course of the Alltan Breac-laraich.

It is clear that certain faults running slightly east of north, or N.N.E., nearly parallel to the foliation of the schists, were in existence before the intrusion of some of the Tertiary dykes, and acted as lines of weakness along which dykes were subsequently intruded. An example of this is furnished by a N.N.E. dyke on the west coast of Loch Caolisport, two-thirds of a mile north-east of Ellary, which has, on its north-west side, a parallel crush breccia, evidently indurated. A thin crush line, seen in the burn about a

quarter of a mile north of Ellary, is also probably responsible for the nearly northern strike assumed by a dyke for nearly a mile and a half.

A few rocky banks and gulleys which strike north-west probably indicate the existence of small faults or strong joints. A Tertiary basaltic dyke, striking locally N.N.W., about a mile north-east of Ellary, is somewhat crushed on its western side. C. T. C.

The hardened crush breccia at the side of the East and West dyke near Ellary, mentioned in a preceding paragraph, is probably the indication, on the west of Loch Caolisport, of a fault which, to the east, is responsible for the course of the Baranlongart Burn. It runs here in two parallel branches, the more southerly being accompanied by the same big quartz dolerite dyke as occurs to the west of Loch Caolisport. G. W. G.

A fault which runs through the hollow between Barmore Island (Sheet 29) and the mainland, produces a marked discordance in the strike, the strata of the island being disposed nearly at right angles to the normal trend: this fault is also accompanied by a considerable throw, the beds on the east side being displaced towards the north.

In North Kintyre a series of north-west step faults (with one exception) displace the outcrop of the Green Beds in the same direction, the south-west sides being shifted towards the south-east. Step faults belonging to this system probably also account for part of the displacement on either side of Loch Fyne, between Stonefield and Ardmarnock, which has already been referred to in connection with the Crinan fault. J. B. H.

Similar faults give rise to conspicuous features in the country between Kilberry and West Loch Tarbert. The indefiniteness of the boundaries of the rock groups in this locality has prevented any accurate determination of the effect of these faults. It is clear, however, that, like the North Kintyre faults, every one displaces in the same way the outcrops of the various schistose divisions which it encounters, those on their south-west sides being shifted to the south-east.

The most interesting feature in connection with these faults is the deflection caused by one of their number in the course of the Loch Caoi-rain quartz dolerite dyke. Their influence upon the direction of the Tertiary set of intrusions is obvious upon the face of the map.

Only two important faults have been detected in Jura. Unlike those of the mainland, just considered, these run in a more or less north and south direction. They occur in the south-west corner of the island (Sheet 27 and Fig 5), and are the continuation of faults known in Islay, across the Sound. Their position is marked on the coast by two great shatter belts: the one determines the straightness of the coast between Faolin Ferry and Inver Cottage, while the other runs along the shore from Rudha Barr nan Gobag to Rudha Aoineadh an Reithe. Their effect upon the stratigraphy of the island has been considered already in Chapter IX. E. B. B.

CHAPTER XII.

PLEISTOCENE AND RECENT.

Ice Movements and Glacial Striæ.

The historical development of our knowledge of the glaciation of the district has already been dealt with in Chapter II.; the accompanying striæ map (Fig. 8) shows how completely the early researches of Dr. T. F. Jamieson in Knapdale and Mr. J. Anderson in Jura have been confirmed by the later work of the Geological Survey.

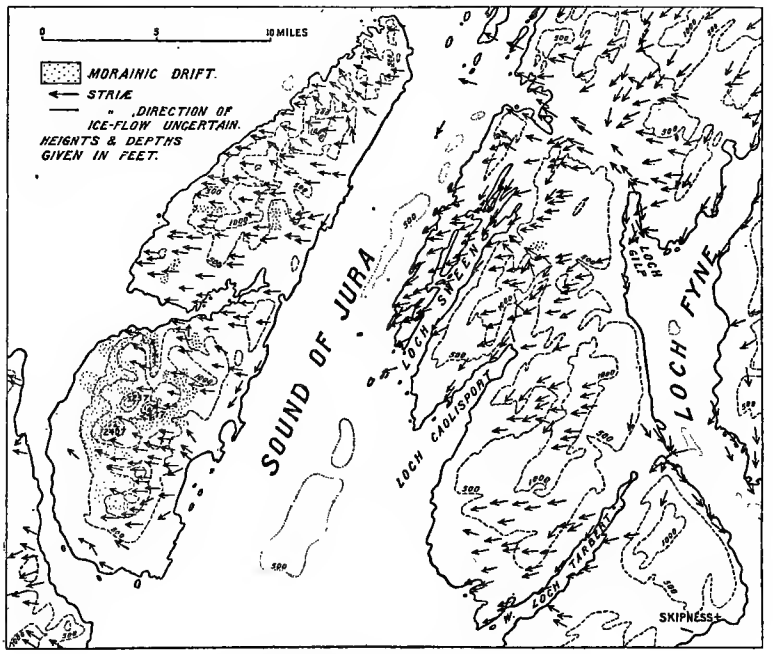

Fig. 8.—Sketch Map of Striæ and Moraines.

The Jura striæ shown on this map are taken from Mr. Wilkinson's observations, and those of the mainland tract have been obtained by the several collaborators in this memoir.

It is obvious that an ice-sheet crossed Knapdale in a west-south-westerly direction, with a tendency to deviation along the more important hollows. In Jura the flow was almost due west, with similar deflections, especially in the immediate neighbourhood of the Sound. How far the striæ found low down in valleys, such as

that of the Sound of Jura, indicate the undercurrents of the great ice-sheet in its maximum extension is uncertain. In many cases they probably belong to late stages in the glaciation, when local features might be expected to have considerable influence in determining the ice-flow. In Jura certainly there are striæ which belong to a stage of definite valley glaciation, characterised by the accumulation of moraines; Mr. Anderson has suggested that these local Jura glaciers may belong to a glacial period quite distinct from that which nurtured the great ice-sheet. B. N. P., W. B. W., E. B. B.

On the mainland, striæ which may perhaps be referred to the creep of local ice, distinct from the movement of the ice-sheet, have been noticed on the west side of the valley which continues northward from Loch Caolisport. Their bearings are roughly W.N.W. and E.S.E., and it appears probable that they indicate a movement of ice in an E.S.E. direction down the hill slopes. C. T. C.

Boulder Clay.

In comparison with the Eastern Highlands, the western regions are comparatively free from glacial deposits, and this district forms no exception to the rule. Over the greater part of the area boulder clay is either absent altogether or occupies small hollows. It seldom extends far up the hill slopes, and thus does little to soften the rugged features of the landscape.

In the district bordering Loch Fyne north of Loch Gilp the boulder clay is of the Upper Loch Fyne type, that is, grey to grey-blue in colour where freshly exposed; in the remainder of the region, on the other hand, the clay is commonly of a deep chocolate or reddish brown hue. J. B. H.

The whole district is included within the cone of distribution of boulders from the Loch Fyne porphyry, which latter occurs as massive intrusive sheets along the north-west coast of Upper Loch Fyne. On the mainland small boulders of this porphyry are abundant as far as the north limit of Knapdale (Crinan, Sheet 36), and in Jura they have been found commonly to within a few miles of the north end of the island. They are also known in Islay, to the south of Jura, and in Colonsay, to the west. These porphyry boulders have more than once been regarded in the past as derived from the Lorne volcanic area, but this is clearly not the case. E. B. B.

Boulders of the Glen Fyne granite are not conspicuously represented in the region as a whole, but many have been noted, as, for instance, near the head of Loch Caolisport. C. T. C.

In connection with the prevalent red colour of so much of the boulder clay, we may note that Mr. Bailey finds red sandstone fragments not uncommon in the boulder clay of the Crinan district (Sheet 36), while Mr. Wilkinson also records them in Jura. In the mainland district included within the scope of this memoir, similar boulders have not been found in the drift deposits, but red sandstone and conglomerate fragments occur to the south near Skipness (Fig. 8).

The best exposure illustrating the method of occurrence of these fragments is afforded in the Skipness Valley near the ruin of Lagangroidh;* the till here is of chocolate to reddish brown hue, usually laminated and often sandy; it encloses some large striated boulders and is full of angular and sub-angular fragments, amongst which are reddish sandstone with rounded borders, but with nearly flat upper and lower surfaces corresponding with bedding planes. Some of them have central grooves parallel to the same planes, and are thus almost divided, each into two pebbles. There are also fragments of conglomerate like that of the Old Red Sandstone, and these appear to have yielded many of the smaller pieces of schist found separate in the till.

It seems likely then that the red colour of the boulder clay is connected with the pre-glacial presence of red sandstones in this district, especially in the large hollows of Lower Loch Fyne and the Sound of Jura. The red sandstones † of Arran and Bute may perhaps be regarded as survivals of Loch Fyne outcrops, while small outliers on the western shore of Kintyre (Sheet 20), near the Mull of Oa (Islay, Sheet 19) and in Lunga (north of Scarba, Sheet 36) have suggested to Dr. Peach a previous wide extension of red beds in the region of the Sound of Jura. Dr. Peach also points to the red staining of the schists along the east coast of Islay as an indication that the red beds here have but recently been denuded away. Indeed, similar strata may occur even to-day in considerable force beneath sea-level. In the Loch Fyne area, the Arran sandstones clearly continue under the sea to the north, while in the Jura region the lavas of Glas Eilean, which are associated with a little red sandstone, extend beneath the waters of the Sound of Islay.

A few details regarding the nature and distribution of the boulder clay may now be given. In the tract between Otter Ferry and Kilmory, the till is very sparsely distributed. To the north of the ferry it forms the floor of a raised beach, and is seen for a depth of 6 ft. with well-marked lamination and a greyish blue colour. It contains large rounded boulders and is somewhat sandy at the top. The till is red between Ballimore and Ballibeg, but this hue has been imparted by hematite found locally in association with mineral veins, and has not the same origin as the colour of the red clays of the southern region.

Between Kilmory and Lochgilphead there is a great development of stiff grey-blue till, occupying the ground above the raised beaches, as far as the District Asylum, and similar boulder clay covers the slopes between Fernoch and Bishopston. Deep sections of the grey-blue till have been dissected by the Cularstich Burn ‡ and the stream immediately north of Auchindarroch. On the slopes between Lochgilphead and Ardrishaig the till is thin; red boulder clay has been noted behind the reservoir at Ardrishaig, and brown till on the slope above. Further south, from Ardrishaig to the southern margin of the map, the boulder clay on the Loch Fyne slopes is of the red type already referred to. It is seen here and there on the coast, as, for

* Almost due north of Coalfin (Sheet 21).
† Both of Old Red and New Red age.
‡ The stream that skirts the Lochgilphead Asylum.

instance, to the south of Ardrishaig, at the southern entrance to East Loch Tarbert, beneath the raised beach at the mouth of the stream south-east of Eilean á Chomhraig, at Morrison's Mill,* Camas na Ban-tighearna, and Luib Dhubh.†

In the inland tract of North Kintyre there is, in the valley at Glenskible, a deep deposit of red boulder clay, which reaches an elevation of 600 ft., and, immediately east of Cruach Tarsuinn,‡ a similar deposit extends to a height of 900 ft. On the western slopes of North Kintyre there are large spreads of boulder clay between Whitehouse and Lonlia.

Another extensive deposit of red boulder clay occupies the hollow of Glenralloch, stretching north-east from the head of West Loch Tarbert. J. B. H.

A reddish boulder clay is found in the Kilberry district as far north as Stotfield. At the latter place the deposit is over 100 ft. thick, and numerous sections in the cliff at the back of the raised beach show that it is a reddish brown sandy clay with only a few stones. The boulder clay found along the upper portion of the Crear Burn is, however, grey in colour. J. S. G. W.

Boulder clay occurs in patches covering the floors of shallow depressions in the lower ground beside Loch Caolisport, and again on the higher ground to the west in the valley of Abhainn Mhor. It is a dull red tough clay containing striated boulders of the schists and some of extraneous rocks, chiefly porphyry. In the burn which flows down into Gleann Cinn-locha from Gleann Tarsuinn various bands of gravel are exposed beneath and mixed with reddish brown boulder clay. C. T. C., H. B. M.

The boulder clay of Jura is, according to Mr. Wilkinson, of a bright red colour, and occupies considerable tracts in the south-western portion of the island.

Erratic Blocks.

Great erratic blocks constitute one of the most conspicuous records of the march of the ice-sheet across Knapdale and Jura. The epidiorite sheets of the district have yielded the largest masses, ranging up to 20 ft. and more in diameter. Several particularly fine examples may be seen from the road east of Loch Caolisport, and Mr. J. F. Campbell § (author of "Frost and Fire") is said to have epecially remarked on one at the foot of an old seacliff near Ormsary House, as the largest he had ever seen. Its original dimensions, before it split across, are given as $52 \times 36 \times 20$ ft. E. B. B.

Moraines.

In Jura, which includes the highest portion of the district,

* About a mile south-east of Eilean á Chomhraig.

† A quarter of a mile north-west of Fionn.

‡ A mile and a quarter W.N.W. of Glenskible.

§ "Sixth Report of the Boulder Committee," *Proc. Roy. Soc. Edin.*, 1880, vol. x, p. 587.

Mr. J. Anderson found great masses of morainic drift accumulated by local valley glaciers. These have since been mapped (Fig. 8), and in part described, by Mr. Wilkinson,* who has also found moraines in Islay to the south, while Dr. Peach has shown that they recur on a small scale in Scarba to the north; it is obvious, in fact, that the quartzite hills of the three main members of this island chain, Islay, Jura and Scarba, nourished independent glaciers at some stage after the withdrawal of the great ice-sheet.

On the mainland the only evidence of this type of glaciation is found in the valley of the Lussa, north of Bacoch's Seat, where there is morainic material in which large boulders are scattered. In the adjoining area to the north-east there is a similar dearth of moraines, very few occurring south-west of the belt extending from Loch Avich, in Lorne, to Caol Ghleann, in Cowal.†

Rock Basins.

There is no large freshwater loch in the district, but there are many small lochs on the mainland tract, while in Jura they say that there is one for every day of the year. It is reasonably certain that the majority of these small lochs are rock basins, and it is therefore interesting to note that they fall quite naturally into place in the topography of the district. The ridges and valleys of this topography, governed by the occurrence of bands of alternately more and less resistant rocks, find their continuations in the headlands and bays of the lochans. E. B. B.

The basin of Lower Loch Fyne extends in a southerly direction past the island of Arran to the submarine plateau which connects South Kintyre with the coast of Ayrshire. The depth of the latter is about 30 fms., and the deepest part of the former is 104 fms.; so that, with a crustal elevation of about 200 ft., the former basin would represent a deep body of fresh water cut off from the sea. As recorded by Dr. Mill,‡ the deepest water occurs in a straight trough about half a mile wide running nearly north-west for 20 miles through the Sound of Bute and terminating opposite Barmore Island. Farther to the north a smaller depression of similar depth occupies the channel to the east of Artilligan. By consulting the Admiralty Chart, it will be seen that the 20 miles of deep water above alluded to, lying below the 80-fathom level, is situated towards the head of the trough, and accords therefore with the evidence adduced by Sir A. Ramsay in support of the view that these rock basins have originated from the erosive action of glaciers. Later, Professor James Geikie,§ in enforcing the same views, called attention to the submarine rock basins occupying the fiords of the West of Scotland. Our knowledge of the bed of Loch Fyne is based on the Admiralty Chart, prepared by the Hydrographical Survey under the superintendence of Captain C. G. Robinson, R.N.,‖ and the

* "The Geology of the Seaboard of Mid-Argyll," *Mem. Geol. Survey*, 1909, p. 98.

† "The Geology of Mid Argyll," *Mem. Geol. Survey*, 1905, p. 134.

‡ "The Clyde Sea Area," *Trans. Roy. Soc. Edin.*, 1892, vol. xxxvi. p. 644,

§ "The Great Ice Age," 3rd ed. p. 232.

‖ Admiralty Chart, Firth of Clyde and Loch Fyne,

RAISED BEACHES. East of An Sailean, Loch Tarbert, Jura.

investigations of Mr. J. Y. Buchanan * and Dr. H. R. Mill, who have published maps showing the submarine contours; the latter observer has supplemented his maps by cross sections. The deepest sounding (104 fms.) was obtained close to Skate Island (Sgat Mhor), about 3 miles from the entrance of Loch Fyne, and, as pointed out by Mr. Buchanan, this is just at the point where the fiord contracts, both as regards its surface and the deeper channel below.† As observed by Dr. Mill, the basin has a very gentle slope near the plateau barrier, but towards the north it gradually becomes narrower, deeper, and steeper in its descent from the shore. He remarks that the steepest part of the slope forms an angle of 25°, and that its greatest depression is the deepest in the Clyde sea area.

J. B. H.

The existence of large isolated troughs in the Sound of Jura has also been proved. There is a small one, too, in the Sound of Islay, and another in the Gulf of Corryvreckan; the latter may be regarded as an over-deepened tributary of the great isolated basin of the Firth of Lorne. The origin of these hollows is probably connected with glacial erosion, as has been suggested by Professor Geikie and others.

Raised Beaches.

Jura.—As already pointed out in Chapter II., Jura has long been famous for its raised beaches. There is a great contrast between the two sides of the island in respect of the development of these interesting features. On the west, for miles, naked and heath-clad shingle beaches fringe the coast, running in occasionally for three-quarters of a mile from the shore, and constantly reaching an elevation of slightly over 100 ft. On the east, high beach deposits are never conspicuous and are for the most part found only at the heads of bays. Further, the lowest raised beach of the west coast is always backed by a fine cliff cut in rock or in the earlier drift and raised beach deposits, while on the east the hill slopes reach the sea in many cases quite unnotched.

The Ordnance Survey has ascertained the levels of a very large number of the shingle spreads, and the result is shown on the six-inch maps. Slightly over 100 ft. is a common elevation, and 120 ft. seems to be about the maximum. Only rarely, as near the mouth of Gleann Asgeamal, are the high-level beaches accompanied by an erosion feature along their inner margins. As a rule they are mere accumulations of shingle heaped up in spits and bars, or distributed evenly upon the fairly level slopes near the coast. The material of the shingle is almost entirely the quartzite of the island; for the most part the shingle is very coarse, and the partially rounded blocks of which it is composed are scarred with concussion bulbs, from beating one against the other in the days when the Atlantic waves were free to play with them. The bareness of many of the shingle

* "The Composition of Oceanic and Littoral Manganese Nodules," *Trans. Roy. Soc. Edin.*, 1892, vol. xxxvi. p. 459.

† Mr. Buchanan obtained manganese nodules from a limited area in the deepest part of the trough, while the other materials dredged were represented by shells and sandy clay. It is said that before that time manganese nodules were not supposed to exist anywhere out of the deepest oceans.

spreads depends in part upon the natural barrenness of the quartzite, in part upon the fierceness of the western winds, and perhaps also on the free drainage between the boulders. Islands of heather are frequently found surrounded by the white sea of the quartzite shingle.

Mr. R. Lunn has taken a series of photographs of the Jura raised beaches, some of which are reproduced in Plates I., II., VI. and VII. The finest examples are to be met with on the north shore of Loch Tarbert and, further north, near Shian Bay (Plate I.).

The lowest of the raised beaches, at an elevation of about 25 ft. above sea-level, is almost everywhere backed by a fine cliff on the west side of Jura. The higher beaches are thus usually left "hanging" upon a platform which is truncated along its seaward margin by the later cliff (Plate VII.). The cliff is extremely picturesque as a rule, and is continually broken by caves, large and small, and buttressed by basalt dykes innumerable. The caves are inhabited every summer season by lobster fishermen.

E. B. B.

Mainland.—The raised beaches of the mainland tract are much more subdued in their development than those of Western Jura. The higher beaches are for the most part merely represented by the arrested deltas of various streams, but the lowest beach, which has been termed the "50-foot beach" in the description of the district to the north (Sheet 36) and the "25-foot beach" in the Clyde area, is everywhere a conspicuous feature. Glacial shell beds have been found in connection with Loch Sween, Loch Caolisport and Loch Gilp.

In the Tayvallich peninsula the lowest beach is backed by a conspicuous cliff; in fact, corresponding with this beach, there is frequently a strongly marked rock notch and very little deposit. The level of the platform is roughly 35 ft. The higher beaches are found specially in the low-lying island of Danna. The best evidence of their presence, however, is a terrace which runs parallel with the road to the west of the head of Loch na Cille; this appears to be a rock notch corresponding to a beach somewhat below the 100-foot level.

B. N. P.

On the other side of Loch Sween and round the Point of Knap to Loch Caolisport, the lowest raised beach forms a well-marked feature, being partly a terrace of deposit and partly of rock erosion. Where bench marks are available, the height of its inner margin appears to be about 30 ft. above sea-level.

J. S. G. W.

A very interesting arctic shell bed has been found by Dr. H. W. Crosskey* lying beneath the deposits of the beach just referred to. It occurs on the protected side of a small bay of Loch Sween, about a quarter of a mile seaward from Ashfield House. It underlies several fields and may be reached by digging. Dr. Crosskey says that the shell clay here may be described as a *Tellina calcarea* (*proxima*) bed, since this Arctic species—so characteristic of the glacial

* "Note on the Glacial Geology of the District around Loch Sween, Argyllshire," *Proc. Birmingham Phil. Soc.*, 1886, vol. v. pt. i. p. 219.

clays of Scotland—occurs in hundreds with the valves united. The arctic *Leda pernula* is very common; and he also found a large valve of *Saxicava* (*Panopœa*) *norvegica*.

Dr. Crosskey's list is given below.

FORAMINIFERA.

Polymorphina compressa *d'Orb.*
Polystomella striato-punctata *H. and M.*

OSTRACODA.

Cythere tuberculata *G. O. Sars.*
Cythere dunelmensis *Norman.*
Cythere lutea *Müller.*
Cytheridea punctillata *Brady.*
Cytheridea torosa *Jones.*

MOLLUSCA.

Astarte compressa *Monty.*
Astarte sulcata *Da Costa.*
Axinus flexuosus *Montg.*
Cardium echinatum *Linn.*
Cyprina islandica *Linn.*
Leda pernula *Müller.*
Leda pygmœa *Münster.*
Mya truncata *Linn.*
Mytilus modiolus *Linn.*
Scrobicularia prismatica *Montg.*
Scrobicularia alba *Wood.*
Tellina calcarea *Chem.* (T. proxima *Brown*).
Panopœa norvegica *Forbes and Hanley* (Saxicava norvegica *Spangler*).
Buccinum undatum *Linn.*
Littorina littorea *Linn.*
Littorina obtusata *Linn.*
Littorina rudis *Maton.*
Natica sp.
Purpura lapillus *Linn.*
Trochus tumidus *Montg.*
Pleurotoma pyramidalis *Ström.*
Utriculus obtusus *Montg.*
Rissoa parva *Da Costa.*

There are boulders in the fossiliferous clay which must have fallen into it during its deposition. Dr. Crosskey also lays stress upon evidence of gradual shallowing of the waters in which the mud collected. *Littorina littorea*, the big Arctic form, comes to be extremely abundant in the upper part of the clay, imparting to this portion of the deposit a distinctly littoral facies.

That this Arctic marine deposit is much older than that of the low raised beach which covers it near the sea-margin here is quite certain. The fauna of the low beach, the 25-foot beach of the Clyde, is everywhere temperate in character. It seems likely that the shell bed is of the age of the 100-foot beach, but the connection, as is so often the case, is far from clear. A poor development of the 100-foot beach has been mapped in this locality, but nothing of importance in regard to it was discovered.

E. B. B.

From Castle Sween to Doide Farms and at the head of Kilmory Bay the 100-foot beach is well marked, but where its inner margin reaches a rocky headland, such as the northern promontory of

Kilmory Bay or the steep rock slopes on either side of the Point of Knap, this beach has left no record of its existence. The inference is that the halt in the uplift of the land at this period was a short one, compared with that during the formation of the lower beach. J. S. G. W.

Between Ellary and Achahoish, on Loch Caolisport, the raised beach, at a height of about 30 ft., is represented partly by a rock shelf and to a less extent by deposits of sand and gravel. Near the Free Church and about 350 yds. N.N.W. of Rudha Garbh, old sea-caves of considerable size have been worn out at the back of this terrace. The cave in the latter locality is called Columba's Cave, and contains a rude pulpit and a cross carved on the rock wall.

In the bed of Allt Cinn-locha, about a third of a mile below Lochhead and not more than a few feet above ordinary high watermark, a shell bed is exposed, which is composed of dark grey loam containing abundant remains of shells, some of which indicate glacial conditions. Mr. T. Scott has kindly examined a collection recently made at this locality by Mr. M'Vey, of the Geological Survey, and from his determinations the following list has been constructed:—

Balanus sp. (may be B. crenatus *Brug.*).
Balanus porcatus *Da Costa.*
Mya truncata *L.*
Tellina calcarea *Chem.* (abundant).
Tellina balthica *L.*
Nucula nitida *G. B. Sowerby.*
Axinus flexuosus *Mont.*, var. (?) gouldii.
Leda pernula *Müll.*
Littorina littorea *L.*
Rissoa parva *Da Costa*, var. interrupta *Adams.*

Mr. Scott states that the presence of *Tellina calcarea* and *Leda pernula* give an Arctic character to the deposit,* but scarcely so marked as that of the lower shell-bearing clays at Greenock. He considers that the *Axinus flexuosus* is hardly typical, and probably belongs to the *var. gouldii* recorded from Loch Gilp, and that the bed may possibly belong to the same epoch as the Loch Gilp shell bed, to be described in the sequel.

Most of the specimens appear to be scarcely full grown, and may, Mr. Scott states, have been living in comparatively shallow water.

As the bed is now several feet above high watermark, it must belong to one of the raised beach deposits, and, in view of the Arctic character of some of the shells, it may be referred to one of the higher ones, perhaps to the 100-foot beach, which is represented in this locality by a rude flat of sand and gravel, extending up Gleann Cinn-locha a considerable distance. C. T. C.

The 100-foot raised beach has given rise to a large sandy flat near Baranlongart, but no rock shelf has been noticed here at this level. The lower beach is represented by a well-marked notch.

G. W. G.

* Speaking of the first of these shells, Dr. J. Gwyn Jeffreys ("British Conchology," 1862–1867, vol. ii. p. 390) says that it is "one of the shells most characteristic of 'glacial' deposits."

Between Ballyaurgan and Ormsary there is a very well-marked rock notch at a height of about 30 ft. above O.D. At the above-mentioned localities the old cliff recedes inland, and at its foot there is a broad gently inclined flat of marine alluvium. Below the farm buildings at Ormsary a thickness of 20 ft. of bedded sand and gravel is exposed in the burn section, but no shells were found.

H. B. M.

To the south of Ormsary a well-defined raised beach extends along the coast at a height varying between 30 and 50 ft. above sea-level. It is chiefly a bench of erosion and for a considerable distance the bottom of the rock margin on its inland side is not, on the average, more than 30 ft. above sea-level; but when it is overlaid by beach deposits, as at Port Cill Maluaig and Miller's Bay, its surface reaches the 50-foot contour.

The 100-foot beach is found in small detached areas at the foot of the Crear Valley, Miller's Bay and near Rudha Cill Maluaig. It has been carved out of glacial deposits, and at the latter place it makes a grassy platform on which stands the site of the chapel and burial-ground of Cill Maluaig, furnishing a well-marked feature in the seascape looking southwards from Loch Caolisport. At these various points this inner margin of this bench, as proved by bench marks and O.S. levels, is exactly 100 ft.

J. S. G. W.

North-west of Tiretigan there are three terraces, corresponding with raised beaches, at about 30, 60 and 100 ft. respectively; the lowest, as usual, is the best marked. South of Tiretigan, on either side of the right-angled bend of the road, coarse quartzite shingle of the 100-foot beach is exposed at the top of the cliff of the lowest beach. The occurrence is distinctly reminiscent of the west coast of Jura, especially as the caves and cliff of the low raised beach are more finely developed here than anywhere else in the mainland tract.

On the north-west side of Loch Stornoway two beaches are well displayed. The higher one is represented by a gravel terrace some 60 ft. above sea-level. At the head of the loch the 100-foot beach is preserved in the form of an arrested delta of sand and gravel.

E. B. B.

Along the shores of West Loch Tarbert raised beach deposits are well represented. Two valleys lead down to the head of this fiord, and one of them is floored, as far as Glenralloch, with alluvium, which probably represents a raised beach deposit, and slopes up the glen from the coast to a height of 80 ft.; the other is lined by a similar deposit, which slopes from the coast to a height of 50 ft. From thence to Tarbert there is a flat, covered with peaty soil, which represents the 50-foot platform, and, as the highest point on the isthmus between East and West Loch Tarbert is 52 ft., Kintyre was doubtless an island at the epoch of this beach.

Turning now to the north-west slopes of West Loch Tarbert, raised beaches are seen at Abhainnghillean, where they have been modified by the stream, and also at Tràigh Bhan, while the 100-foot beach occupies a ledge near the high road above. An alluvial strath extending south-westward from Torrantuirc represents in

its upper portion the 100-foot beach, while the material further down has been re-sorted by the stream that follows the course of the hollow. The 100-foot beach also occurs in the entrance of Glen Achanaglachach, to the south of Craig Lodge, at Dunmore, and at the head of a valley nearly half a mile north-east of Achens.

On the south-east side of West Loch Tarbert the 100-foot beach is represented at West Tarbert and Eascaird. Between Tigh-na-Coille and the bay east of Rhu Point, the lower raised beaches are well developed, while higher terraces between 50 and 100 ft. occur further up the slope at Achadacaie. These deposits cover considerable tracts between Whitehouse and the coast from Kilchamaig Bay to Gartnagrenach Bay, and they are also represented to the north of Redhouse.

Raised beaches fringe those portions of the coast of Loch Fyne (Sheet 29) where the declivity is slight; they are generally well developed at the seaward ends of the principal valleys, but in these localities have been considerably modified by the streams, and merge into the alluvial terraces formed by the latter. They are mainly composed of coarse gravel, in which sands play but a subordinate part, and their floor is very commonly formed of boulder clay. The raised beach occurring at a low level and generally known as the 20-foot or 25-foot beach is the best developed, but the higher beaches, extending beyond 100 ft. in height, are also represented in the more protected inlets. The higher beaches were laid down before the close of the glacial epoch, as is shown by the fauna of the shell beds and by the relations of the beaches to the moraines at the head of Loch Fyne.*

A small deposit of the 20-foot beach is seen at West Kames, and another resting upon boulder clay occurs to the north of West Otter Ferry. Beaches of 20 ft. and ranging up to 50 ft. in height line the hollow fronting Port Ann, and at Achnaba the 50-foot beach is represented, mainly by a rocky platform with isolated patches of gravel. About a quarter of a mile north-west of Silvercraigs a small patch of the 50-foot raised beach is again seen, while relics of the deposit at lower levels skirt the edge of the promontory below Castleton House.

On the shore between this promontory and Creaglan, a shelly clay is exposed which is probably an extension of the Arctic shell bed, which is described below, at the head of Loch Gilp. Between Castleton House and the pier below Kilmory, the 50-foot platform is marked by a rock ledge, while at higher levels the 100-foot beach is represented by thin disconnected patches of gravel. From Kilmory to Lochgilphead these marine terraces form a great expanse of arable land, and extend up the slope beyond the 100-foot level. In the valley at Bishopston, beaches extending from 20 to 50 ft. in height flank the eastern slopes, but the 20-foot beach has been dissected and considerably modified by the Badden Burn, which flows into the head of Loch Gilp from the north.

* "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, p. 144.

Along the course of the Badden Burn Sir Archibald Geikie * and Mr. Crosskey † have found several exposures of a glacial shell bed comparable with those described above in Loch Sween and Loch Caolisport. They saw the shell bed at intervals from a little below the bridge of the Lochgilphead-Ardrishaig Road to beyond Badden Farm (Sheet 37). It is a grey clay or clayey sand, and lies upon grey boulder clay with an abrupt line of junction. The fauna is so abundant that in places the bed becomes a mass of shells bound together in a slight matrix. The freshwater stream, Mr. Crosskey remarks, is sometimes "literally paved with *Mya Uddevallensis*."

Sir Archibald Geikie published the names of several shells from this bed, remarking that it is full of the usual northern species. He also observed that specimens of *Mya truncata* are particularly abundant, rows of them standing together with their siphonal ends upwards; some have bored down into the boulder clay below, and many of them are so perfectly preserved that the siphon itself remains intact.

Messrs. Crosskey and Robertson ‡ note that the composition of the deposit varies from place to place, becoming more or less sandy as the case may be. At one point, too, it is overlain by "about a foot of gravelly clay, with boulders of various sizes thickly interspersed, not unlike a shore shingle. In this gravelly clay, *Mya truncata* is exceedingly plentiful in its natural boring position, with both valves united." It seems not impossible, from this description, that the upper deposit here may belong to a much later raised beach than the lower clay and sand, so that the very complete list of shells given by Messrs. Crosskey and Robertson from this locality may perhaps include two distinct faunas.

The life of the period represented by the shell bed certainly varied from point to point according to local conditions. "At one spot *Mya truncata* abound, the shells being thickly packed in a sandy matrix. At another, this shell is absent, and *Saxicava rugosa* stands in its natural position, and *Astarte borealis* is found with united valves. The smaller shells and even the Entomostraca equally vary in grouping at different points. We have, in fact, all those local varieties of *habitat* characterising a sea bottom. There is no sign of any confused sweeping of one part into another."

Although this shell bed lies at a low level, it certainly does not correspond with the 20-foot beach, for the fauna of the latter, where preserved, is always of a temperate facies. The Arctic fauna in this case points to a connection with one of the upper raised beaches, probably that at 100-foot level.

The western slopes of Loch Gilp are comparatively steep, and the raised beaches are consequently not so well preserved. The 100-foot beach, however, is well developed at Auchindarroch, although it merges into the 20-foot beach; a gravel pit has been opened in this deposit about a quarter of a mile north of the mansion. The 20-foot beach forms disconnected strips along the coast as far south as Whitehouse Bay, and in the vicinity of Ardrishaig furnishes the

* "The Glacial Drift of Scotland," *Trans. Geol. Soc. Glasgow*, 1863, vol. i. p. 137.

† "Glacial Deposits of the Clyde District," *Trans. Geol. Soc. Glasgow*, 1867, vol. ii. p. 47.

‡ The Post-Tertiary Fossiliferous Beds of Scotland," *Trans. Geol. Soc. Glasgow*, 1871, vol. iii. p. 118.

sites of numerous villas and gardens that skirt the shore. At Inverneil raised beach deposits are well developed and extend up the slope beyond the 100-foot level, while a smaller set of gravel platforms, from the 100-foot terrace downwards, occupies the front of the valley at Stronchullin, where the gravels have been eroded and partly redistributed by the stream, which follows a sinuous channel through them. From Stronchullin to the southern edge of the map (Sheet 29) the shores are precipitous, and platforms on which these deposits could repose are rare. Small ledges covered by gravel occur, however, at Mounterins and Milmore, which are occupied by the mansions and policies of those estates, and another small patch is seen below Stonefield. A relic of the 100-foot beach occupies a ledge to the south of the north Lodge of Stonefield, and is the sole example of this deposit between Stronchullin and the southern edge of the map. The slopes of Loch Fyne south of Tarbert are even more rugged than to the north, and raised beaches are absent except for two small deposits at Lagganroaig and Altagalvash. J. B. H.

Peat and Alluvium.

Peat is widely distributed in small patches, which occur in the valleys or upon the flat hilltops. There is no large peat moss in the district. Wide alluvial flats are also absent, as might be expected from the small size of the rivers of the district. Many of the marshy hollows now occupied by peat and alluvium were formerly the sites of small lochs. E. B. B.

CHAPTER XIII.

ECONOMIC RESOURCES.

Mineral Ores.*

The existence in this region of copper, lead and silver has long been known from the mining operations conducted in the past on the properties of Castleton (Shirvan), Inverneil, Stronchullin and Erins. These undertakings, however, do not appear to have been attended with success and were of a limited nature, but the recent discovery of gold at Stronchullin (Sheet 29) has created a fresh interest in the mining possibilities of the region. The discovery of gold was the result of an analysis made by the Tharsis Copper Company of Glasgow for Mr. R. C. Graham Campbell of Shirvan, the owner of the property, who sent a specimen from one of the abandoned workings at Stronchullin for a report on its value as a copper ore; although the sample showed a discouraging yield in its cupriferous contents, the analysis revealed the unexpected presence of gold, and to the high value of two ounces to the ton.

This auriferous ore was extracted from a small lode lying a quarter of a mile distant from Stronchullin Farmhouse, just south of the Stronchullin Burn and to the east of the sheepfold. It is marked on the six-inch ordnance map (Argyll 180 N.E.) as "Lead Mine." At present there is an open-work along the lode running nearly north and south, for a length of about 80 ft. and a depth of from 10 to 18 ft., the latter being at the south end of the working, in the direction in which the ground rises. That part of the lode which has been worked consists of a narrow quartz reef, enclosing variable amounts of lead, copper and zinc ore; it has a maximum thickness of from 15 to 18 in., and dips steeply to the westward at about 70°. The mine was originally worked for lead, but the spoil heap shows that copper and blende were also present, and these minerals are likewise seen in the new excavations conducted recently by the proprietor. As the gold is invisible, it is presumably associated with one or more of the other minerals, either as a fine mechanical admixture or in chemical combination, and until the property has been further developed, and the source of the gold better understood, the extent of the auriferous deposits cannot be ascertained.

A later sample tested by the Tharsis Company yielding results approximately similar to the first, a larger parcel of 1 cwt. was treated by them, two tests from which yielded 1 oz. 12 dwt. 15 grs. and 1 oz. 9 dwt. 9 grs. respectively to the ton, with a somewhat smaller amount of silver, while the copper and lead contents were about 1 and 2½ per cent. respectively. Another sample of the same size produced

* This account was written in 1908.

still higher values, in which gold was represented approximately to the extent of 5 oz. per ton, the two analyses from the sample being as follows:—

Gold, per ton.			Silver, per ton.			Copper, per cent.	Lead, per cent.
oz.	dwt.	grs.	oz.	dwt.	grs.		
5	1	6	4	8	20	1·42	10·42
4	18	0	4	12	6	1·47	10·77

Other analyses, resulting in high gold values, were carried out by Messrs. Vivian & Son and Messrs. Henry Bath & Son, both of Swansea, the former firm reporting, in addition to gold, silver, copper and lead, the presence of 11 per cent. of zinc, 5 per cent. of arsenic, and 9 per cent. of antimony.

Encouraged by these results Mr. Campbell despatched a consignment of 10 tons of ore to Swansea, which was sold to Messrs. Vivian & Son at a remunerative price, and this was followed by another consignment of similar amount. The mineral contents furnished by the smelters were as follows:—

	Gold, per ton.			Silver, per ton.			Copper, per cent.	Lead, per cent.
	oz.	dwt.	grs.	oz.	dwt.	grs.		
1st Lot	1	4	12	2	8	0	1·20	2·10
2nd Lot	1	9	7	2	16	0	1·70	3·9

Of these lots, the second consignment was more carefully selected and contained a larger proportion of mineralised stone. The total copper and lead contents rose from 3·30 per cent. in the first consignment to 4·79 per cent. in the latter. In spite, however, of this proportionate increase of about 45 per cent., the excess of gold in the second consignment is only about 19½ per cent., while the silver has only increased by about 16¾ per cent.

The results of Messrs. Vivian's concentrations of one of the earlier samples (No. 12) were as follows:—

Original Sample—

Copper	1·8	per cent.
Zinc	11·9	„
Lead	10·1	„
Silver..	3·2	oz. per ton.
Gold	2·28	„ „

1 lb. was washed and dressed. The concentrates weighed 3 oz. 10¼ drs. and yielded:—

Copper	2·2	per cent.
Zinc	14·6	„
Lead	21·5	„
Silver..	6	oz. per ton.
Gold	7·05	„ „

Slimes weighed 11 oz. 11 drs. and yielded:—

Silver..	2 oz. per ton.
Gold	·45 „

In the original sample 5 per cent. of arsenic and 9 per cent. of antimony were also obtained.

Neither the results of this concentration nor a comparison of the analyses of the two lots of 10 tons afford any clear indication of the source of the gold. As regards the silver, the figures of the above concentrate are more suggestive, the increasing proportion of that metal being commensurate with that of the lead, both having doubled in the concentrate, a fact which points to the conclusion that the silver is associated with the lead. These proportions, however, are not repeated in the comparative analyses of the two parcels of 10 tons, in which, although the lead has increased by 47 per cent., the silver only shows an increase of about 16¾ per cent. It is probable, therefore, that the relative proportions of silver and lead are inconstant, and the gold may vary still further in its mineral association. In any case, the evidence is insufficient to afford any clear indication of its mineral affinities, although its association with copper pyrites is not improbable, in which case the colour, in a sufficiently fine admixture, would not be distinct enough to facilitate its detection. Although the microscopic slides show, amid the copper pyrites, tiny specks that may possibly represent gold, the nature of these specks has not been demonstrated. At one time it was suspected that the gold was in association with blende, but such examination as has been undertaken does not confirm this hypothesis, although small traces of gold were indicated in the blende.

The quartz vein probably occupies a fault fissure, but the evidence is insufficient to prove this, as it lies quite regularly between bedded quartzites, and the latter are themselves silicified in the vicinity of the lode. Beyond the open-workings the continuity of the lode is difficult to trace, but towards the south end of the excavations the silicified quartzite may probably be found to act as the leader. To the south of the mine, vein quartz is exposed on the hillside, and higher up Gleann da Leirg, in the main stream about half a mile S.S.W. of the mine, a quartz vein occupies a fissure which has likewise been infilled by a basalt dyke. The quartz carries but slight traces of mineral. To what extent these quartz veins south of the mine may be connected with one another and the lode already worked is uncertain. They occur, however, in the same general line, and probably belong to the same system of veining. It is equally uncertain how far the lode extends northerly from the mine, but there are some old workings on the north side of the burn.

About 250 yds. to the south-east of Srondoire (Sheet 29) there is much iron pyrites and a little lead, which permeates and veins the quartzite and, as analyses shows, carries some gold and silver. This is nearly on the same line as a similar pyritous zone seen on the shore half a mile E.S.E of Stronchullin.

About 1¾ mile south-west of Stronchullin a small copper lode occurs in the bed of a tributary stream of the Stronchullin Burn, and

is cut by a basalt dyke. Mr. Graham Campbell states that the lode at this point is about 3 ft. wide, and that a specimen yielded to analysis 17 per cent. of copper, and carried 17 oz. of silver and about 1 dwt. of gold to the ton.

On the south side of Artilligan Burn, about a quarter of a mile from the sea, a "Lead Mine" is marked on the six-inch map. It consists of an adit running W. 10° S. A similar trial occurs on the spot* marked "Lead Mines" on the same map on the south side of Allt na Dunaiche, where excavations have been made in a quartz vein on the line of a fault running W.N.W. along the bed of that stream.

About $1\frac{3}{4}$ mile south west of Erins (Sheet 29) copper was formerly mined, but the undertaking was unremunerative, the expense of conveying the ore to the coast along the hill tract by mule pack being in itself excessive. Although copper is evidently present in quantity in the rocks, the existence of well-marked lodes has not been proved. In the neighbourhood of the copper mines, which occur close to the burn east of Cruach nan Cuilean (Sheet 28), the quartzose schists show yellowish to greenish hues and carry much copper pyrites. The hill of Meall Mor to the north yields similar traces of copper, and cupriferous schists of this type are also noted one mile E.S.E. of Meall Mor and a quarter of a mile E.S.E. of Cruach nan Cuilean.

J. B. H.

A metalliferous vein occurs across the watershed, at the foot of Coire Mhaim (Sheet 28); it is about 8 ft. wide and cuts the Erins Quartzite. The gangue is composed of dolomite, with quartz and albite, and contains scattered specks of chalcopyrite and zinc blende in fair abundance.

J. S. G. W.

Between Stronchullin and Inverneil a fault fissure, which follows the course of the stream reaching the coast a quarter of a mile north of Creagan Beag (Sheet 29), encloses a vein which is highly charged with chalybite. The vein is several feet in width, and runs about S. 60° W.

The most extensive mining in the district has been undertaken on the property of Inverneil, for the extraction of lead in the tract bordering Cruach Mheadhonach (Sheet 28) and the Inverneil Burn. The most important working appears to be that on the slopes of the above-named peak, where there is an adit, at the foot of the hill about 150 yds. from the road, and a line of vertical shafts running approximately N. 30° W. for about a quarter of a mile; towards its upper end a small open-work, 1 to 2 ft. wide, runs N. 30° W. and hades 10° to south-west.

About a quarter of a mile north of Auchbraad (Sheet 28) there is a 10-foot vein of quartz, running north-east, which is seen in one place to be in contact with an epidiorite, and carries traces of galena and pyrites. On the north side of the Inverneil Burn, about a third of a mile above the bridge of Auchbraad, there is an open-work on a north-easterly quartz vein, which is from 12 to 18 in. wide and carries lead and pyrites. About two-thirds of a mile above the same bridge and south of the stream, there are small adits and traces of lead in strings and specks in the material of

* About a third of a mile south-west of Mounterins.

the spoil heaps. The workings along the glen on the south-west side of Cruach Mheadhonach are confined to small trials. These lead veins of Inverneil are found in a group of quartz schists and phyllites, in which thin limestone seams are occasionally interspersed, and the phyllites themselves are slightly calcareous.

In the neighbourhood of Loch Errol (Sheet 28) the rocks, which are of similar composition to those just mentioned, are largely stained with brown, yellow and green hues, and copper is evidently widely diffused. This is especially the case near the loch itself, in which it is stated that fish are unable to live. While the copper is generally in a state of diffusion, giving the prevailing discoloration to the rocks, the lead occurs in small quartz veins, three of which are seen on the northern shores of the loch, but the width of the largest is only 2 ft. Two of these veins run north-east and south-west and coincide approximately with the strike of the rocks, while the third runs north and south. The strata consist of silvery mica schist or phyllite and quartz schist.

On the north side of the road, about a mile south-west of Loch Errol, a small quartz vein, carrying galena, cuts across a limestone band; the outcrop runs slightly east of north and hades 50° south-east. Another quartz vein, from 1 to 2 ft. in width, has been worked for lead a quarter of a mile west of Loch Fuar-Bheinne.

West of Loch Errol, on the south side of Lochan Dobhrain near the outlet, a quartz vein 2 ft. 6 in. wide, in epidiorite, runs S. 25° W. and hades 30° S.E. In it Mr. Wright observed traces of lead and copper, and remarks that the same vein is obscurely seen, with a thickness of 2 ft., on the north side of the loch.

J. B. H.

A 4-foot quartz vein, seen in the plantation 70 yds. north-east of the Free Church at the head of Loch Caolisport (Sheet 28), shows a slight green staining occasionally. The vein runs roughly N. 25° E. and appears to continue for about a mile in that direction. Another large quartz vein is exposed nearly half a mile north-west of Lochhead, but this appears to be quite barren. Various quartz veins, an inch or two thick, occur in the epidiorite of Rudha Garbh, Loch Caolisport, and one of them contains a considerable proportion of iron pyrites. In an epidiorite on the north-west side of Eilean na h-Uamhaidh, close to the locality last mentioned, a small lenticular quartz vein contains a little copper pyrites. By the roadside 300 yds. south of Ballyaurgan, east of Loch Caolisport, a large white quartz vein has been quarried for road-metal; it seems to contain no metal.

C. T. C.

On the east side of Loch Gilp a quartz reef, about 6 ft. wide, has been worked for copper on the Castleton * Estate in the vicinity of Ballimore; it dips steeply to the west and contains copper pyrites, galena and some iron ore; analysis also yielded about 4 dwt. of gold to the ton. The lode runs partly in epidiorite and can be traced to the shore, where it is truncated by a basalt dyke. The various outcrops are not in alignment, and have possibly been shifted by faulting. To the north-east they are of similar irregularity,

* Now known as Shirvan.

and are seen in the rock exposures between Ballibeg and the east lodge of Castleton (Shirvan).

These mineral lodes may be connected with the granitic intrusions of the Lower Old Red Sandstone or early Silurian period, but the evidence on this point is far from conclusive. In the first place, the lodes all lie in the Ardrishaig Group of schists, and especially in its siliceous portion. Now, this group further to the north-east, near Inveraray,* is also metalliferous, and has yielded ores of nickel and copper that appear to be connected with the great quartz porphyry intrusions of that region. Before reaching Knapdale, however, this suite of intrusions has died out, save for a few lamprophyre sheets of the same age. The lodes, however, where they occur as definite veins, have a prevailing north-easterly or north-north-easterly direction, which agrees with the older system of fracture accompanying the Palæozoic volcanic disturbances, and in one instance, near Ballimore, a lode is actually cut by a Tertiary dyke. While, therefore, the Knapdale ores may be linked with the Newer Granite intrusions of the Highlands, the possibility must also be borne in mind of their having been leached out of the crystalline schists amid which they occur. J. B. H.

Glass and Silica-Bricks.

Jameson, a hundred years ago, remarked that the quartz sand along the western shores of Jura is among the purest that nature affords, and that it has been used with much success in the making of fine glass; he states that it is worthy of becoming generally known in this connection, and that it might also be advantageously used, in place of powdered quartz or flint, for the making of smalt and different kinds of porcelain.

Some of the quartzite of the south-west corner of the island, for example, near Inver Cottage, is so pure that it deserves a trial for silica-bricks. The same quartzite occurs in Islay, *e.g.*, at Bonahaven, where it might perhaps be more conveniently worked, if its quality proved satisfactory. An attempt in this direction has in fact been made, by Mr. M. Hurll, in Eilean Dubh Beag (Sheet 36), many miles to the north. The result was unsatisfactory, for the bricks obtained from a sample of 100 tons yielded at too low a temperature, becoming pasty. At the same time the analysis of the quartzite appeared favourable, being given as follows:

Silica.	Al.	Iron.	Lime.	Mag.	Alkali.
97·65	1·66	0·23	0·24	0·10	0·12

There is so much quartzite apparently of great purity, however, that further trials seem desirable, especially in the north of Islay.

Slate and Limestone.

Black pyritous slates, resembling those of Easdale, were formerly wrought at Tarbert and Ardlussa in Jura. The quarries date back for more than a hundred years, and have been long abandoned owing to the inferior quality of the slates. A grey slate, of apparently

* "The Geology of Mid-Argyll," *Mem. Geol. Survey*, 1905, p. 151.

better quality, has also been wrought at Tigh a' Mhuilinn beside Linue Mhuirich in the Tayvallich peninsula, but the work has been discontinued.

Limestone was formerly quarried and burnt in many localities, and the Danna limestone is still occasionally wrought and distributed along the coast by boat. E. B. B.

Building Stone and Road-Metal.

The quarrying of building stone and road-metal has been restricted to the local demand. The epidiorites are frequently used for both purposes, and the fissile varieties, which are readily dressed, have been chiefly made use of for building. Quarries have been opened on such bands both at Lochgilphead and at Ardrishaig.

Basalt has been seldom used for building purposes, as the irregularity of its jointing renders it expensive to dress; but where utilised it constitutes an excellent stone, and when its dark hues are relieved by red sandstone mouldings and quoins, the combination is attractive. This rock has been wrought for macadam where the dykes are sufficiently accessible to the main roads.

Amongst the sedimentary schists the best building material is furnished by the Green Beds, which have been extensively wrought for this purpose at Tarbert. The quartzites of the Ardrishaig Group often yield excellent stone, and some of the more compact bands of the Ben Bheula and Stonefield Schists have also been quarried.

Road-metal is supplied by almost every type of rock included in the district, the best material, perhaps, being furnished by the limestones in the Erins Quartzite, for use on the road along the north-west side of West Loch Tarbert. Convenience of position in many cases has led to adoption of very inferior metal.

J. B. H.

General.

The west coast of Jura, and also the north coast of Islay, might well be used as a source of white quartz gravel for garden paths. It is to be hoped, however, that the wonderful raised beaches of these islands may never suffer injury for such a purpose.

Peat is little used, for, on the mainland, it frequently lies upon flat hilltops a considerable distance from any dwelling, and coal is readily imported from the Clyde. Even the peat used in the Ardrishaig Distillery is imported from Ireland. In Jura the local peat supplies both inhabitants and distillery.

Sheep farming and fishing are the main occupations of the sparse population of the mainland, while Jura is in the main given over to deer. There is from the nature of the topography very little arable land, the main patches being restricted to raised beach and boulder clay deposits near the sea lochs. Fifty or seventy years ago much more corn was grown. The local mills, such as those of Miller's Bay and Muileann Eilean Bagh, were once fairly numerous, but are now all in ruins. Timber is restricted to local plantations, but the results are good and show that the lower slopes of the mainland at any rate might readily be afforested. E. B. B.

Ellary House is provided with an electric installation, water-power being derived from a small reservoir on Ellary Burn about half a mile above the house. Other streams in the district have a more rapid fall than the Ellary Burn, and might be utilised to yield power on a moderate scale. The annual rainfall in the parts of Knapdale and Kintyre included within this description varies greatly from place to place, but seems to be about 60 in.* The fall in the basin of Loch Sween is said to be only about half that at Ardrishaig.

C. T. C.

* The Royal Scottish Geographical Society's Atlas of Scotland, 1895, plate iii., shows the average annual fall for twenty-five years to be 61¾ in. In April, May and June the monthly fall is generally less than half that in October, November and January.

APPENDIX.

LIST OF WORKS RELATING TO THE GEOLOGY OF THE DISTRICT.

1790. Pennant, T. A Tour in Scotland and Voyage to the Hebrides; MDCCLXXII. 4to; London. vol. ii. pp. 243–249.

1800. Jameson, R. Mineralogy of the Scottish Isles; with Mineralogical Observations made in a Tour through different parts of the Mainland of Scotland, and Dissertations upon Peat and Kelp. 2 vols. 8vo; Edin. and Lond. Jura, vol. i. p. 166.

1808. Jameson, R. Mineralogical Queries. Query No. 21. Is the granular quartz of the islands of Isla and Jura subordinate to mica-slate, or does it constitute a distinct formation? *Mem. Wern. Soc.*, vol. i. p. 117.

1814. MacCulloch, J. Remarks on several parts of Scotland which exhibit Quartz Rock, and on the Nature and Connections of this Rock in general. *Trans. Geol. Soc.*, vol. ii. pp. 450–487.

1814. MacCulloch, J. Miscellaneous Remarks accompanying a Catalogue of Specimens transmitted to the Geological Society. *Trans. Geol. Soc.*, vol. ii. p. 414.

1819. MacCulloch, J. A Description of the Western Islands of Scotland, including the Isle of Man: comprising an Account of their Geological Structure; with Remarks on their Agriculture, Scenery and Antiquities. 3 vols. 8vo; Loud. vol. ii. pp. 182, 282; vol. iii., plate xxiii. fig. 3. With a general map of the Western Isles, and one of Isla, Jura, Colonsa, Oransa, geologically coloured.

1824. Vetch, Capt. Account of some Terraces, or ancient Beaches, in the Isle of Jura. *Trans. Geol. Soc.*, Second Series, vol. i. [1821–1824], p. 416.

1840. MacCulloch, J. A Geological Map of Scotland. Published by order of the Lords of the Treasury. By S. Arrowsmith, Hydrographer to the King. [Scale, 4 miles to an inch.]

1844. Nicol, J. Guide to the Geology of Scotland, with Geological Map. 8vo; Edin.

1855. Bedford, J. E. Notice of some Raised Beaches in Argyllshire. *Quart. Journ. Geol. Soc.*, vol. xi. p. 549.

1858. Nicol, J. A Geological Map of Scotland.

1861. Jamieson, T. F. On the Structure of the South-West Highlands of Scotland. *Quart. Journ. Geol. Soc.*, vol. xvii. p. 133.

1861. Murchison, Sir R. I., and [Sir] A. Geikie. On the Altered Rocks of the Western Islands of Scotland, and the North-Western and Central Highlands. *Quart. Journ. Geol. Soc.*, vol. xvii. p. 171.

1862. Jamieson, T. F. On the Ice-Worn Rocks of Scotland. *Quart. Journ. Geol. Soc.*, vol. xviii. p. 164.

1862. Murchison, Sir R. I., and [Sir] A. Geikie. First Sketch of a New Geological Map of Scotland, with explanatory notes.

1863. Geikie, [Sir] A. The Phenomena of the Glacial Drift of Scotland. *Trans. Geol. S c. Glasgow*, vol. i. pt. ii. p. 137.

1865. Geikie, [Sir] A. The Scenery of Scotland viewed in connection with its Physical Geology. Jura, p. 214. And later editions.

1867. Crosskey, H. W. Glacial Deposits of the Clyde District. *Trans. Geol. Soc. Glasgow*, vol. ii. p. 47.

1871. Crosskey, H. W., and D. Robertson. The Post-Tertiary Fossiliferous Beds of Scotland. *Trans. Geol. Soc. Glasgow*, vol. iii. p. 118.

1876. Argyll, Duke of. On the Physical Structure of the Highlands in connection with their Geological History. *Nature*, vol. xiv. p. 435; also *Rep. Brit. Assoc.* for 1876, p. 81.

1880–84. Reports by the Committee on Boulders appointed by the Society. *Proc. Roy. Soc. Edin.* Sixth Report, 1880, vol. x. pp. 586, 591, 634; Seventh Report, 1882, vol. xi. pp. 253–256; Eighth Report, 1882, vol. xi. pp. 743–746; Ninth Report, 1884, vol. xii. pp. 193–200; Tenth and Final Report, 1884, vol. xii. pp. 775, 776, 779, 781.

1883. Wadsworth, M. E. Notes on the Lithology of the Island of Jura, Scotland. *Proc. Boston Soc. Nat. Hist.*, vol. xxii. pp. 485–489.

1886. Crosskey, H. W. Note on the Glacial Geology of the District around Loch Sween, Argyllshire. *Proc. Birmingham Phil. Soc.*, vol. v. p. 219.

1888. Anderson, J. Glaciation and Raised Beaches in Jura and Islay. *Trans. Geol. Soc. Glasgow*, vol. viii. p. 316.

1892. Buchanan, J. Y. The Composition of Oceanic and Littoral Manganese Nodules. *Trans. Roy. Soc. Edin.*, vol. xxxvi. p. 459.

1892. Geikie, Sir A. Geological Map of Scotland, reduced chiefly from the Ordnance and Geological Surveys. Edin.

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1898. Geikie, Sir A. *Summary of Progress of the Geological Survey* for 1897. Jura, pp. 64, 152.

1899. Geikie, Sir A. *Summary of Progress of the Geological Survey* for 1898. Jura, p. 50–52, 75, 172.

1899. Hill, J. B. On the Progressive Metamorphism of some Dalradian Sediments in the Region of Loch Awe. *Quart. Journ. Geol. Soc.*, vol. lv. p. 470.

1900. Geikie, Sir A. *Summary of Progress of the Geological Survey* for 1899. Jura, p. 65, 147, 163.

1901. Geikie, Sir A. *Summary of Progress of the Geological Survey* for 1900. Jura, p. 48, 141.

1904. Teall, J. J. H. *Summary of Progress of the Geological Survey* for 1903. Knapdale, pp. 67, 68, 69, 73, 74.

1905. Teall, J. J. H. *Summary of Progress of the Geological Survey* for 1904. Knapdale, pp. 53, 66, 71, 72, 73.

1906. Teall, J. J. H. *Summary of Progress of the Geological Survey* for 1905. Knapdale, pp. 90, 92–95.

1907. Teall, J. J. H. *Summary of Progress of the Geological Survey* for 1906. Knapdale and Kilberry, pp: 77, 81.

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